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AN INTERPRETATION OF WINTER ECOLOGY EXPERIENCES AT THE HIGH SCHOOL BIOLOGY LEVEL

by

© ROBERT BRUCE DRYSDALE

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "An Interpretation of Winter Ecology Experiences at the High School Biology Level", submitted by Robert Bruce Drysdale in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Secondary Education.

K.G. Jacknicke
Supervisor

M.F. Wideen
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Date Oct. 3, 1983

ABSTRACT

This study attempts to reveal the meanings that students and teachers give to a laboratory/field-oriented snow ecology unit as well as to the laboratory experience in high school biological sciences. These meanings are used to evaluate one perspective of the worth of the snow ecology unit and the laboratory enterprise in science programs.

The snow unit was developed over a period of four years in order to introduce biology students to the importance of snow as a factor in the Canadian environment. Basic concepts were selected from research writings in boreal ecology, and the format of presentation based on educational research into laboratory activities, projects and field studies. The unit was designed to fit within the curriculum specification of the Alberta Biology 20 program.

An examination of current evaluation research trends in science education indicates that traditional quantitative studies, based on tight statistical analyses and following the "scientific method", are now being complemented by qualitative techniques which attempt to describe and interpret educational settings "in situ".

The state of research into the effectiveness of laboratory work in the biological sciences was examined. Little definite support was found for the laboratory

component of biology programs other than for content, which does not require laboratory work and/or process skill development. Regardless, both researchers and teachers have indicated highly positive effects of laboratory work on the students and classroom atmosphere which have not been formally evaluated.

A qualitative study using situational interpretative methodology was used to obtain data on the worth of the snow ecology module. Three classes of Biology 20 participated in the study, including one class being taught by the writer. Observations were made on the writer's class and interviews were conducted with eighteen students and two teachers.

Interviews were taped, then transcribed. Each individual's comments were gathered into a series of short paragraphs and a written interpretation prepared by the researcher. These descriptions and interpretations were returned to the participants for validation.

The meanings the participants gave to the snow ecology unit were examined using a framework developed by Rothe (1979). Meanings were placed into one of four Areas of Being and the responses were grouped according to major themes which became apparent during the examination of the interview data.

Participant responses indicate that laboratory activities have meanings in the Passive, Immediate and

Responsible Area of Being, that the experience is of considerable value to most of the participants, and that the removal of the laboratory from a biology program would reduce the worth of that program.

The snow ecology unit was thought to have been quite successful. Though the concepts and content could have been taught in class without laboratory activities, the participants stressed that the impact of "hands on" experience gave the unit its significance and helped to develop a more positive attitude to the winter environment.

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CHAPTER 1

INTRODUCTION TO THE STUDY

Purpose of the Study

Laboratory activities have traditionally been a component of senior high school biology curricula. In 1982 the National Science Teachers Association presented a position paper which indicated that a major goal of science education in the 1980's was to help students to become scientifically and technologically literate and re-emphasized the importance of laboratory and field activities in helping to meet this need. While considerable lip service has been paid to the effectiveness of the laboratory experience, suggested by the multitude of articles in biological and science journals and personal contact with science teachers, little formal evaluation has been conducted by science educators into the worth of these activities, whether they are carried out in the familiar indoor laboratory setting or outdoors in the field.

This study attempts to reveal the interpretations which teachers and students give to biological field studies, using a series of winter ecology activities designed by the writer.

The study should provide the participants by their involvement in the investigation, with a better understanding of the laboratory/field experience and hopefully, through description and analysis, provide other educators a forum for exploring the meaning these experiences have for them. This study should also

a) help educators arrive at a better understanding of what it means for both the student and the teacher to experience field work in winter ecology.

b) provide additional background and resource materials in an area of biological science generally ignored by the current texts and materials available in the Alberta biology curriculum.

c) provide teachers and students with some suggested field activities that can be run during the winter season, the major part of the school year in this region of Canada.

The Laboratory as an Effective Teaching Strategy

Science education in Canada has been heavily influenced by research not only in education but in the sciences themselves. This is illustrated by the number of well designed and tested American programs such as P.S.C.S. Physics, C.H.E.M. Study and B.S.C.S. Biology, developed for senior high schools during the 1960's, which emphasized the laboratory. Recent concerns for environmental problems have triggered an even greater stress on the role of the laboratory in the biological sciences. Nevertheless, it was still necessary for the National Science Teachers' Association Commission on Professional Standards and

Practices (1970) to make the following comment (Bates 1978):

> The time has surely past when science teachers must plead the case for school laboratories. It is now widely recognized that science is a process and an activity as much as it is an organized body of knowledge and that, therefore, it cannot be learned in any deep and meaningful way by reading and discussion alone.

The laboratory is a costly enterprise. Special rooms have to be designed to meet the many needs of modern science activities. Equipment and materials make up a considerable portion of a school's annual budget. A major question often being asked is whether students get something from laboratory experiences that they cannot get from lectures, films or demonstrations (Bates 1978). If a gestalt exists, it does not seem to have been articulated clearly. School boards and school administrators, as well as science teachers and students, are required to make decisions on the worth of laboratory/field activities.

However, the decisions mentioned above cannot be made only in terms of cost efficiency. The worth of the laboratory as a teaching strategy is of prime consideration. The classroom teacher must be able to justify and thus support the use of laboratory activities to himself, his colleagues and his superiors. The students also have a role to play in any such decisions.

Evaluation research into the many facets of the laboratory/field work experience, using a variety of techniques, would appear necessary in order to provide much needed information for educators to evaluate this aspect of science education.

What, then, are some of the basic considerations educators should give to the laboratory experience? According to Schwab (1966) the laboratory should display the phenomena which gives rise to problems, ways of gathering data to solve these problems and all the inherent difficulties one can expect. The laboratory should also provide the setting for conducting "scientific" thinking and eliminate the artificial distinction between classroom and laboratory, as well as *knowing* and *doing*. Watson (1978) noted that psychologists from Rousseau to Piaget have emphasized that experiences, whether from everyday living or predetermined in a school setting, form the basis of learning. Those activities which are school-planned could be amplified by laboratory, museum or field settings. Each setting is considered as contributing to the full range of learning: cognitive, affective, aesthetic and skill. Each setting also allows the participant to have a personal, non-verbal experience with the things and interactions of the world.

Bates (1978) examined the role of the laboratory in secondary school science programs. He notes that most research on science instruction has been centered on content acquisition. The few studies conducted in other areas have used empirical methods of limited validity.

Thus, there is considerable difficulty in making any definite statements on the role of the laboratory. He suggests that teachers who believe the laboratory accomplishes something special for their students would do well to consider what is accomplished and look for means of evaluating this effect. He asks the question, "What does the laboratory accomplish that could not be accomplished as well by less expensive and less time-consuming alternatives?". He also notes that there appears to be a general acceptance of laboratory activities as having a definite place in science programs.

In discussing out-of-the-classroom field studies, Koran (1979) noted the lack of the clear data which would support the apparent value of this type of experience:

> Even though the literature on field trip effectiveness is not definitive, both teachers and students extol the positive virtues of such experiences beyond what one would expect, given the results of research at this point in time. This suggests that beneficial effects of "out-of-school" learning may not yet have been explored or completely measured. For example, one potential positive effect which does not seem to have been reported is the rejuvenating effects on both teachers' and students' psyches. The exhilarating effects of getting out of the routine may well have positive long-term therapeutic benefits. But how do we measure these?

The lack of any supporting evidence for laboratory activities is certainly well illustrated in the above quotation.

Novak (1976) stressed the importance of lab and field studies in biology. Experiences with real objects are needed to form primary concepts (give meaning to concept labels such as cell, climax vegetation) in order to develop secondary concept formation (ecosystems, metabolism). He notes that while Piaget placed stress on hands-on experience for children, this type of activity is needed at all ages. He further states that although lab and field experiences can be designed to test for concept meaning (enquiry learning/problem solving experiences), concept learning and development are probably more important. The social exchange of the laboratory and field activities can lead to positive affective responses, attitudes and values. Again there is a lack of supporting evidence. However, educators must consider, at least in quantitative terms, much of the possible value inherent in the lab experience.

To summarize, although there is considerable intuitive support among teachers and science educators for the laboratory/field experience, supporting quantifiable evidence from the evaluation of these activities is highly limited. Information on the worth of the laboratory is required before intelligent decisions on its future in science curricula can be made, decisions which involve both monetary and learning aspects of this educational situation.

The major thrust of this study is to reveal the meanings that a laboratory experience has for its participants, classroom teachers and students. With this information, comments can be made as to the worth of both the snow ecology unit and the laboratory activities it exemplifies. In effect, the laboratory is being evaluated within the limits of this study.

Evaluation as an Educational Endeavour

Evaluation, a major activity in the field of education, has a variety of definitions. These depend on the evaluators involved and the subject of the evaluation. Since an evaluation, with its associated methodology, is part of this study, some comments on both its meaning in general and within the specific context of this research would appear necessary.

Taba (1962) describes evaluation as determining what behavioural changes have occurred in students, and include not only the mastery of context but also the reactions of the students to this context. Scriven (1967) distinguishes between formative (assessing during the formation of programs) and summative (assessing completed programs) evaluation. Formative work appraises programs during development in order to improve their quality. Summative evaluation must result in a decision based on the merits of the program. This separation allows a researcher to focus on one specific aspect of a curriculum evaluation.

Popham (1975) refers to formal evaluation in education by using the phrase "systematic educational evaluation" which is an assessment of the worth of educational phenomena:

> The educational phenomena that are to be evaluated can include many things, such as the outcomes of an instructional endeavor, the instructional programs that produce these outcomes, education products used in educational efforts, and the goals to which educational efforts are addressed.

He also notes that a low emphasis on the evaluation of the affective domain has only recently concerned evaluators. Because the affective refers to attitudes, values and interests and are of an individual nature, evaluation techniques appear to be limited in number.

Werner (1978) defines evaluation as "a sense making or interpretive activity" by the evaluator. The evaluation in a school situation is coloured not only by each student's personal reactions but also by the biases of the evaluator. He thus notes that any evaluation "is colored and moulded by the initial perspective used for interpreting and defining his experience of a school program". This definition, of an interpretive nature, is a departure from the more objective definitions presented by Taba, Scriven and Popham. It reflects, to a considerable extent, his research methodology which differs from the more generally accepted quantitative method involving considerable statistical analyses.

Jeffcoate (1981) stated that the aim of evaluation is to determine the impact of teaching on knowledge, sensitization, opinion and attitudes. Evaluation must include regard for views and interpretation. He found that interviews in which recording devices were used helped in this respect. He sees pupils not as single objects to be tested but as autonomous actors entitled to their own interpretations and opinions. It is important to know what an innovation has done for their knowledge, thought and feelings. Students have their own views on the successes or failures of a program, as well as on its strengths or weaknesses.

In this research investigation, the writer defines his concept of evaluation in similar terms to Werner and Jeffcoate. A description of the dominant research methodology used in evaluation research, along with some alternative approaches which can be used to examine certain situations, is more extensively described in Chapter 3.

CHAPTER 2

THE LABORATORY IN SCHOOL BIOLOGY PROGRAMS

This chapter provides the reader with an overview of the value of laboratory activities to both the students and teachers of high school biological science. The laboratory is defined, and its place in school biological science programs is described. Following a number of illustrations which attempt to convey the impact of field work on both teachers and students, actual evaluations of some laboratory activities are described and discussed. Problems in evaluation methodology are noted.

Defining Laboratory Activities

Laboratory investigation involves some or all of the many processes used by scientists in their day-to-day work. The locale is irrelevant. Although typically viewed as a special room or area in a school building where science is done, it is obvious that a laboratory, in the true sense, is found wherever a scientific study is taking place. In the biological sciences, this is often outside the confines of a building, where organisms may exist in their natural environment. In fact, many investigations require both outdoor and indoor activities in order to accomplish a single goal. This is exemplified by a study which might involve the examination of pond organisms in their natural environment followed by a collection of the organisms which are later examined in more detail in the school laboratory. The unit designed by the researcher is in this category. For the purposes of this dissertation therefore, field work and field activities are synonymous with the laboratory enterprise, and further discussions will reflect the outdoor aspect of laboratory activities.

The Importance of Outdoor-Oriented Laboratory Experiences

Liebherr (1961) aptly comments on the significance of outdoor work in school biology:

> How many times have you emphasized to your class that biology is the science of living things and then proceeded to teach the course using dead specimens? How often have you taught the processes of biological cycles and then failed to take your classes into any natural environment where these cycles could be seen in operation?

Besides suggesting the value of outdoor investigations Liebherr reveals a problem which, for whatever reasons, exists in many biology classrooms: the emphasis on content learning rather than on students' experiencing the realities of living organisms, systems and environments. During my own years of teaching I have observed this phenomenon on numerous occasions. The lack of biological background by a teacher, apparent time constraints in covering course material, and even winter as a seasonal problem haven been mentioned as reasons for the limited use of field work in biology programs. One should thus ask whether the laboratory experience really has positive value to teachers and students or is it simply a routine demanded by a curriculum, an activity we would well do without.

Brennan (1967) states that since scientists go to the environment to gain an understanding of it, the student must go there also. Since most living things are outdoors we must go out-of-doors to learn about and experience their natural environment. In the outdoors conditions and lessons change continuously; there are real measurements to be taken, real questions to be answered and real situations to be studied. The constant changes in the outdoor environment confer a permanent "open end" to the experience.

If, as Brennan (1967) states, an appropriate aim in education is to develop in the student "an interest in what he is learning and with it an appropriate set of attitudes and values about intellectual activity generally", the laboratory, as an integral component of biology programs, should assist in accomplishing these goals. An investigation of the activities being carried out in the classroom would tend to support the positive aspect of the field laboratory experience.

The Value of the Outdoor Laboratory

The literature on field activities points to the highly positive effects of field work on the students. This enthusiasm appears in turn to have encouraged teachers to continue with these activities, indicated by their desire to share these experiences with other science educators through journal articles. The representative examples which follow illustrate these effects and reflect the resultant teacher enthusiasm for continuing field studies with their students.

Brown (1959), working with two groups of grade nine science students studying the pattern of plant succession for its impact on organism interdependence, found that the classes exhibited an enthusiasm considerably greater than in regular classes being taught the same topic, but without field work. Bullington (1959) noticed a definite 'esprit de corps' development in a winter field experience with college students, supported by numerous student comments indicating that the field work learning experience was the high point of their college careers. In working with primary school children, Greene (1967) indicated that the children were tremendously interested in field biology phenomena and were thrilled with opportunities to "discover" in the outdoors.

Abraham, Kennedy and Liebherr (1966) are convinced that the study of organisms in their natural environment provides a learning experience that has both immediate and lasting value and that the experiences gained can motivate the students to read about what they have experienced. This can serve to bridge the gap between the written text and the actual experience of observing and working with organisms. Students freely state that in the case of activities at the Eagle Lake Biological Station, weeks of classroom study cannot equal four days in the field. Soderberg and Thompson (1969) found that the side-effects of their oceanography outdoor activities were almost as valuable as their teaching for concepts and skills. They resulted in stimulation of what had been considered dull material by the students. The student reaction had an obvious positive effect on the teachers in return. According to Roth (1961), following class field studies, a group of his high school students organized themselves, on their own initiative, into a field biology club which subsequently took part in a number of investigations conducted by recognized biological agencies. The field activities had apparently affected their attitude toward biology as a meaningful lifetime experience. Berry (1974) noted similar effects following a river ecosystem field study by two-year college students.

It is seen then that enthusiasm for biology at a level not previously observed in students and attributed to field work has been noted by a number of instructors. In addition, Highfall (1977) mentioned an increased use of the knowledge gained in regular classroom activities and frequent student reference to their field experiences. Baer (1977) thought field studies had a deep meaning for students which he considered of "immeasurable" value. Although he was unable to describe the overall effects with more precision, it would appear that both he and his students gave many personal meanings to the activity.

Lee (1977) conducted school roof top field studies with his high school biology classes monitoring autumn hawk migration. Following the experience Lee observed that the overall results were difficult to assess, since effects seemed to be different for each student. While a few kept their involvement to a minimum, others became deeply involved. Many students joined ornithological organizations, went on out-of-school field trips, or simply visited natural areas on their own initiative. Most seemed to have developed an awareness for the place of hawk species in the ecosystem. Individual meanings given to the experiences were clearly observed. Lee was not attempting to evaluate the program in a formal manner yet even his "gut reactions" could not be effectively communicated. In this sense, apparent values became value-less to anyone assessing the field program. Jernigan and Wiesch (1978) also indicated positive but intangible effects of an environmental studies unit, yet mentioned these effects in their own evaluation of the program.

The studies cited all appear to have a common theme. Students who participate in laboratory/field studies appear to have a more positive approach to all aspects of biological science, both in and out of the school situation. This indicates that special meaning is given to this experience and cannot be confined within the walls of the school. Equally obvious in the students is the great difficulty encountered when trying to identify what these meanings may be and in what ways the activity segment of biological studies is interpreted by both the individual student and teacher. Allen (1975) reflects this feeling when he suggests that field investigations, using natural phenomena, act as a springboard to raise questions about the meanings of the participants' own lives and to reflect on their lifestyle aspirations. The learning attained from field experience lies not only in what meaning it makes of the world but also in what it makes of the learner.

Evaluations of Outdoor Laboratory Activities

From the preceding remarks, the reader may feel that formal evaluations of laboratory work have not been attempted. An investigation of the literature indicates that while there is definitely a lack of research into this aspect of science education, a limited number of studies have been completed. The following paragraphs summarize the results obtained from these studies, generally based on the dominant research methodology used in science education, and relying on quantitative data, statistically analyzed, to help arrive at educational decisions.

One of the earliest studies of this nature was conducted by Harvey (1951) on a group of grade nine general science students, who were to study the biological impact of fire on the environment. She attempted to measure the effect of the field trip on the scientific attitude of the student as compared with a control group, studying the same topic but within the classroom situation. Her definition of field trip was "a carefully planned and evaluated excursion outside the school building, an integral part of the instructional program in which each student takes an active part".

The material presented to both groups was new. Both groups were pre-and post-tested by a self-devised instrument. It was discovered that at the 0.01 level, the two methods of instruction produced significantly different results, not attributable to intelligence, in favour of the students experiencing the outdoor work. The field trip in this study was of short duration, a matter of two fifty-five minute classes. The laboratory apparently had more of an impact on the students than a strictly classroom exposure to the same topic. However, only that aspect of the experience which could be quantified, improvement in process skill learning, was evaluated. No mention was made of the feelings of the participants, after they had completed the unit.

Bullington and Wittrup (1970), during the development of an activity methods biology unit involving prospective teachers and high school students, used a prepared questionnaire to evaluate the field experience portion of the unit. The popularity of learning based on meaningful activity and involvement was an obvious effect. Students, both high school and college, indicated that their involvement in the outdoor setting was a high point in their educational experience. They felt that field work involved the living or real world. Working in small groups was very much preferred to large group work. Data were quantified and, although some indication of participant impressions was suggested, individual meanings were not obtained nor was an attempt made to do so.

Riban and Koval (1971) investigated longer term field studies in the high school. The field work extended over a four day period in particularly miserable weather. The students tested had never taken a previous biology course and were working as assistants to senior biology students. A B.S.C.S. developed test was used to determine knowledge of the essentials of scientific method and design, and was administered in a pre-test, post-test design. The initial versus final scores were significant at the 0.05 level. The mean gain was similar to that of students having taken B.S.C.S. biology (process skill oriented) for a full year and better than those who had completed a conventional content oriented biology course. As in Allen's study, skill improvement, relatively easy to quantify, was the only aspect of the activity evaluated.

Simpson (1973) indicated that science educators were becoming aware that a student's behaviour is influenced as much by how the student feels as by how much he cognitively understands. Evidence is mounting that behaviour is affected by such things as interest, likes and dislikes, feelings, attitudes and values. He noted that very little information seemed to exist on how to evaluate learning in the affective domain, and that it might be possible to use some recently developed empirical techniques. Although he appeared to recognize that an educational experience is complex and quite individual he still equated evaluation with quantitative methods of investigation.

A more recent study by Chrouser (1975) produced significant results on tests comparing two classes of students (prospective elementary teachers), both given the same classroom instruction. The laboratory sections were equally divided into an indoor and outdoor group. In both cases identical principles were covered, the indoor group exclusively by indoor methods, the outdoor group exclusively by field methods. He concluded from his findings that the outdoor laboratory was more effective than the indoor laboratory in helping students achieve (a) understanding of the social aspects of science, (b) understanding of selected biological principles and (c) understanding of science as process. More highly positive attitudinal behaviours were observed in the outdoor group, although no attempt was made to evaluate them. Implications of the research included an observation that effective use of the outdoors results in a better understanding of one's role in the environment and society. He further states that there is no substitute for a field laboratory in this kind of preparation at a time when awareness and understanding of the environment could potentially mean individual and social survival. A Piagetian flavour is noted when he comments that the student is able to begin his study with low-level abstractions and work to higher levels at his own rate. Again, the evaluation involves content, not the personal meaning these activities had for the students. The positive attitudes that seemed to develop from experiencing the outdoor laboratory were noted but not evaluated.

Frazer (1978) used student and teacher opinions on learning environments and teaching materials during an evaluation of the Australian Science Project. Data were collected by means of a questionnaire. He noted that case studies appear to provide a more sensitive and comprehensive picture of what actually goes on in a classroom situation. Many teacher misunderstandings in presenting materials were revealed. Although meanings and interpretations of the participants were not specifically investigated and that data gathering was, in part, quantified, an indication that empirical techniques should not be the only means of evaluating classroom activities was clearly suggested.

Saunders and Dickinson (1979) compared the effects of a lecture-only versus lecture-laboratory biological science program on community college students. Although few empirical conclusions could be made, they did consider that the lecture-laboratory situation may have been better, as the students seemed to have a more positive attitude toward biological science. Once again, the results of an empirical study also revealed a value component which was not nor could not be quantitatively measured, yet was used, without substantial supportive evidence, to come to some conclusions on the worth of the laboratory.

An empirical study by Blum (1981) attempted to measure the effects of an environmental science curriculum on students' leisure time activities. As previously described, a number of biology instructors had observed that students involved in field studies often became involved in biological activities outside the school environment. Blum concluded that a guided but open-ended inquiry approach with meaningful environmental contact, focusing on field experiments, can affect students out of school activities. Although his study indicates something about activity design, specific reasons for the effect of field work on student meanings are not revealed.

In the evaluations described above, the cognitive and skill aspects of the laboratory were readily examined by empirical methods. However, investigators, although recognizing that there were affective/meaningful implications to the laboratory experience, found great difficulty in evaluating them. No specific study on the meanings/values of the laboratory situation to the student or the teacher has apparently been attempted. It would appear that empirical techniques, which dominate evaluation research, are incapable of such a study and that alternative methods are required to provide this information.

The limitations of the traditional research methodology and the use of qualitative techniques to examine science programs are discussed in Chapter 3.

CHAPTER 3

APPROACHES IN EDUCATIONAL EVALUATION

Paradigms in Educational Evaluation

The research methods generally followed in the social sciences and specifically in science education are unquestionably founded on the techniques used in pure and applied science. Kuhn (1970) describes the scientific research method as a paradigm, a term that indicates the accepted models that lead to a certain tradition of research. The dominant paradigm in science education is founded on "the scientific method" with its concomitant stress on objectivity and quantification. The methods of investigation adopted by the scientific community for the study of scientific phenomena have been, with few exceptions, accepted in principle by educators as the basis of investigation in a social science field. However, recent literature in education is beginning to suggest that the present research paradigm may require considerable rethinking, particularly in light of the different "subjects" of study between the natural/physical sciences and those of a social nature. One must seriously question whether a research method developed to investigate natural phenomena, using objective evaluation tools, can be applied to a field in which the subjects are alive, thinking, dynamic and interact consciously with the researcher and the techniques being used. The following paragraphs illustrate this concern.

In 1972, Glass stated that more emphasis should be placed on evaluation so that the worth of a program, product or procedure might be determined. He was concerned that the scientific/technical paradigm was an inappropriate approach for evaluative investigation. Glass emphasized that one does not have to be able to explain a phenomenon to evaluate it. The scientific paradigm in the sciences is founded on stability of the basic "laws" of science, whereas when the same paradigm is applied to the social sciences, the stability is considerably reduced. The relationship between variables in education appear and disappear often as a function of extraneous conditions and one can never really know when to expect the relationship. Glass further states that if physical laws are as unpredictable as the laws governing education systems, to get out of bed would be dangerous. Glass is reflecting disenchantment with the traditional research paradigm but does not suggest alternative methods. Again, some of the problems in social sciences research were illustrated by Shaver and Larkins (1973), noting the emphasis on objectivity. The evaluator attempts to remove himself from the situation, and design an instrument that measures only the small sample of behaviours which lends itself to measurement, often becoming more familiar with the library than the students, which limits the "size and number of slices of reality" being investigated. Investigative methods, such as those employed by ethnographers, are more holistic because of the researcher's immersion into the problem and the lack of built-in limits and predetermined variables.

Bowen (1975) concluded that quantification of data based on tight research designs and statistical analyses are only partially successful and, without eliminating this basic research paradigm, there is a distinct need to turn elsewhere for alternative research techniques. Patton (1975) was much more emphatic in his observation on the current research methodology. He stated:

> ... the very dominance of The Scientific Method in evaluation research appears to have cut off the great majority of its practitioners from serious consideration of any alternative research paradigm.

He strongly suggested an "alternative" paradigm as a valid means of evaluation, a paradigm that focuses on the meaning of human behaviour and indicates an active role for the evaluator by being partly inside the phenomena to be observed. The research techniques would rely on those developed from the anthropological rather than natural science and require, among other activities, participant observation, interviewing of those involved, detailed descriptions and qualitative field notes.

Evaluation in Science Education

Evaluation in science education poses special problems to program evaluators. Its practitioners are usually science educators, often trained extensively in the pure sciences, thus viewing research in terms of the scientific/technical paradigm. Science education, however, is as much a social science as any other area of education and any criticism of evaluation research techniques must equally apply to this field. Lowery (1980) supports this criterion when he writes that since science education research was developed during a time of considerable scientific enterprise, the research paradigm developed was based on the scientific paradigm. One should note that The Journal of Research in Science Teaching, one of the most prestigious science education research journals, only commenced publication in 1963, following major achievements in the Soviet Union space program and the resultant concerns raised as to the quality of contemporary American school science programs. At this point the evaluation of traditional and newly developed school science programs became a major priority in education research. Lowery also notes that the effect was to apply methods from the pure sciences to a different area of endeavour, science education, which is within the parameters of the social sciences. He further contends that there has been such a concern with scientific methodology that, in many ways, researchers have lost touch with the educational questions they have been asking. A survey of evaluation publications over the past twenty years reveals an almost exclusive use of highly quantitative methods using a multitude of statistical analyses, at various levels of probability, to support or reject science programs and learning techniques. Lowery mentions that methods from other fields might be employed to identify the impact of science education from the point of view of the learner and to examine social interactions in science education settings, situations he feels are not measurable in terms of the scientific paradigm.

I was an instructor of high school science, trained in the scientific method and teaching students to use scientific process skills. The selection of a methodology to evaluate the impact of the designed laboratory unit from the perspectives of those involved reflected my own background. My initial reaction, the search for a quantitative method which would allow for a precise statistical analysis, ended in confusion. Skills and content appeared measurable but not personal interpretations. I then began to review the literature of science education to determine whether there were acceptable approaches to evaluation which might focus on the gathering of qualitative rather than quantitative data. Although limited in number, articles were available which, if nothing else, questioned the exclusive use of quantitative methods.

In 1962, Heath, while discussing the evaluation of new science and mathematics programs, suggested that more useful information would probably result from a number of studies performed under a variety of conditions. Information on the effects of student enthusiasm for the subject matter would seem to bear higher priority and help to provide a more realistic basis for the total assessment of programs.

Atkins (1967) noted a bias in favour of the scientific/technical paradigm to the exclusion of other modes. As a result, problems studied in education research often turn out to be trivial or bear little relevance to classroom practice. Activities in a classroom are both complex and subtle, making social outcomes and values difficult to quantify. Atkins suggested that research should be based on education theory and rooted in classroom situations, resulting in a greater reliance on intuition and aesthetic dimensions for making decisions. He stressed therefore that research should have a naturalistic setting and requires an interpretive approach. The field of ethnology might, he thought, provide new perspectives in evaluating classroom events.

Welch (1974) again expressed the concern of some science educators that data gathering techniques used by evaluators are usually selected from the field of measurement, whereas evaluation appears to require more emphasis on attitude, opinions and values. The worth of a program, and thus the judgement of people, is vital. His suggestions for evaluation, however, did limit themselves to available quantitative methods.

In a position paper, Power (1976) again stressed the dominance of the "agricultural-scientific" paradigm in educational research and that its methods were developed initially for research in agriculture and the sciences. He noted that there was evidence of disenchantment with the narrow viewpoint science presents in the social sciences. He feels that science education is too immature to support a single paradigm and recommends that a paradigm based on anthropological methods be used to attempt to understand educational phenomena. He felt that there were pressures within the research establishment which would probably maintain the traditional paradigm as "the" research method.

Yager (1978), in discussing priorities for research in science education suggested that methods used by anthropologists, in which the researcher attempts to observe and report what actually occurs rather than testing preconceived ideas, might be a useful addition to the research repertoir. Thorough reports, ranging from individual students' through small groups' or class observations, could provide data on the moment-to-moment microdynamics of learning. He indicated that the diagnostic potential of this research method would appear to have considerable value.

The techniques used in the evaluation of the Australian Junior High School Science Education Project materials (Frazer 1978) indicated that, unlike most evaluations, a considerable proportion of the research effort was on the direct observation of classroom events, and through questioning student interpretations of the learning environment. Teacher opinion surveys, to determine program strengths and weaknesses plus case study approaches were also used. Data collection involved, in part, the use of both television and tape recordings for the observation of direct classroom activities. Teacher opinions were solicited by questionnaire. The case studies approach involved detailed qualitative descriptions collected without any predetermined criteria in the actual classroom. Although the results were less generalizable in a traditional sense, they appeared to provide a more sensitive and comprehensive picture of the actual happenings within the classroom. The study revealed that important differences existed not only between classes but between individual students within a class. Also, some serious misunderstandings among the teachers were discovered. It was felt that these facts would not have been revealed using only the generalized data collected in a quantitative type of evaluation.

Lowrey (1980) reflected on the focus of the 1979 conference of the National Association for Research in Science Teaching, improvement in research in science education. He reiterated that research strategies in science education developed in the scientific era and that in an attempt to produce respectable results, science educators had tried to be more scientific than educational in their techniques. He also indicated that educators tended to use psychological theories in research and thus contribute to the field of psychology, not education. Psychology and education are not synonymous since education encompasses content and teaching as well as the learning aspects of psychology. Since psychological research styles have also been copied from science, the scientific method with its extensive use of statistics in drawing conclusions may be inappropriate. The research often becomes too data oriented and sometimes appears to lose touch with the basic questions being asked. Lowrey felt that many alternative research methods, such as those used in literature, fine arts and aesthetics, remain untapped. In fact, Lowrey suggested that research in science education is at a stage in its development where many frameworks for gathering information of educational importance should be welcomed as, "fresh research methodologies appropriate to the enterprise". This idea certainly appears to have considerable merit.

By 1982, qualitative evaluation was becoming an accepted addition to the methods of science education research. Rist (1982), Roberts (1982) and Smith (1982) described the advantages of techniques based on ethnographic and anthropological paradigms as means of collecting and interpreting qualitative data. All emphasize the importance of observing, talking to, and participating with people in order to understand them and their behaviour. Qualitative methods are not viewed as "the" method to be used in evaluation research but as a complementary tool which should provide a holistic picture of programs in science education. Field methods would include careful observation of the actions in real life situations and in-depth interviewing. Video and audio taping would be useful to the researcher in recording details which could not be personally observed. Open-ended questioning without a prespecified questionnaire would tend to uncover more personal meanings held by the participants about a science program. Smith argued that if qualitative methods can lead to a description of a phenomenon in its context, traditional testing methods could then follow with even greater effectiveness. Roberts, however, warned of the problems in reporting investigations of a qualitative nature compared with those of quantitative research, which has had a long period of time in which to develop acceptable presentation techniques. It appears that, despite the problems, the overall benefits to our understanding education situations is enhanced by this alternative paradigm.

Although not written in the context of educational evaluation, Aikenhead (1980) set the following scenario which clearly illustrates the need for viewing situations from a variety of perspectives:

> Maps are very useful for specific purposes. Take the map of Saskatchewan for instance. If one wanted to drive to Warman, Saskatchewan, a road map

> might give the following information: its location, what highways lead to it, the category of highway, the presence of campsites, the approximate population, and the presence or absence of an international airport. Some maps could furnish information on the soil conditions, types of vegetation found near the town, and elevation above sea level.
>
> However, with all the data available from maps, one would have no idea: what Warman looks like, what the real estate conditions are, what a proposed uranium refinery did to split the town into fractions.
>
> If one is interested in the real Warman, there is no substitute for being there. But if one is satisfied with a schematic representation, maps are useful. Maps are representations of reality, with much of reality left out.

To determine the realities of either a town in Saskatchewan or a biology class in a senior high school, requires interaction with the actors in their real world. Since information on meanings, values and the worth of laboratory experiences was the purpose of my research, a qualitative rather than a quantitative approach seemed more capable of producing significant information. Qualitative investigations, though still few in number in science education, have now been generally accepted as an effective alternative evaluation approach, particularly if used to complement research findings from quantitative investigations.

An Interpretative Evaluation Approach

To help in determining a qualitative methodology for use in my study, I turned to the work of Aoki, Werner, Wilson and Rothe. They had developed and used qualitative evaluations with some success during the examination of social studies programs. It appeared that their techniques might prove useful in my own endeavour.

In 1978, Aoki, describing the status of education research in social studies, suggested that researchers can fit into a tri-paradigmatic framework based on the work of Habermas and van Manen. These three approaches, empirical-analytic, situational interpretative and critical theoretic could provide alternative viewpoints in curriculum research and evaluation. Empirical-analytic orientation equates with the scientific/technical paradigm; situation-interpretative orientation is evaluated in terms of the meanings people give to situations; critical theoretic orientation stresses reflection that arrives at hidden root assumptions in order to improve humanness and the human/social condition. The combination of the three research areas would provide a more adequate overall view of the evaluation problem. No one method is by itself sufficient for a comprehensive evaluation. Aoki indicated that this tri-paradigmatic model provides alternate avenues for research, curriculum development and curriculum evaluation. Werner (1978) used this tri-paradigm research model to fit the problem of educational evaluation based on the frame of reference or perspective of the evaluator. His model of general sense-making activities is outlined in Figure 1, and was developed during the evaluation of three social studies programs from 1975 to 1977 in Alberta and British Columbia.

Ends-means (seeking to achieve prespecified ends) uses the scientific/technical paradigm as its main evaluation tool. Werner perceived problems in that the evaluation method may in fact shape the aims of the evaluation. The problem fits the research design and considerable significant information may be lost. What the evaluator sees is often restricted by the tools at hand. As a result, the data collected may in the end have little to do with the real life or social situation they are attempting to describe. Rather than abandon this methodology, Werner suggested that situational sense-making and critical sense-making evaluations be added to the evaluation repertoire.

Situational interpretations attempt to uncover the relevance and meaning a program has for those involved. The evaluator interprets questions asked of the participants which attempt to extract personal meaning and the level of relevance the program produced. Each participant, whether student, teacher or evaluator, brings his own expertise and knowledge to the program and is required to offer his own interpretations and experiences as a result of participating. The evaluator attempts therefore, to bring out by discussion the various interpretations, criticisms and opinions of worth by the participants. The result should be common-sense descriptions of the program, unique to each person involved.

Critical interpretation attempts to make explicit the beliefs, descriptions and intents underlying a program; that is, the foundations of the program. Often these are hidden and require questions on the part of the evaluator which probe and uncover fundamental views which include "presupposed standards, logics, images of man and the future, assumptions about knowledge, criteria of what is worth pursuing, root metaphors and perspectives". Its aims are broad, ranging from self reflection by educators and the implications of these beliefs and interests, providing, thereby, a basis for reorientation and change.

Both situational-interpretative and critical theoretic orientations are referred to as emic-evaluations (Wilson 1978) as they express information in terms of the insider interrelationship with the social world and other individuals. Experiences are defined and interpreted by persons in their daily life activities. Emic refers to a point of view originating from within a group and expresses beliefs, values and customs of the group under study. Wilson used the term "etic" to refer to an evaluation framework external to the situation being examined and normally using a quantitative methodology.

The Use of Emic-Evaluation in Education Research

Two extensive studies have been conducted in western Canada in which situational-interpretative evaluation as an evaluation strategy was examined from a theoretical/philosophical point of view and subsequent evaluation techniques developed in order to complement the normal evaluation paradigm. Wilson (1976) described an emic-evaluation inquiry approach which assumes that individual experience provides worthwhile knowledge for program evaluation. Rather than adopt an outsider's concern for efficiency (normative evaluation) the "actor's" concern for quality of life is the value by which individuals give meaning to the various activities in which, as humans, they are involved. The emic point of view must therefore be discovered. Wilson used participant observation and interviewing as methods for obtaining descriptions of daily activities and used them in an evaluation of optional units in a school program. Classroom improvement was seen in terms of the meaningfulness ascribed to the program's activities. The everyday world was considered the main reality giving meaning to classroom activities. Wilson recommended that not only further energy be directed toward evaluation investigation but that decision-making aspects of educational evaluation be studied in terms of practical knowledge. Emic understanding is aided by the procedures of ethnomethodology. Activities in a program should be developed to provide opportunities for teachers and students as individuals to create their own meanings from objective curricular materials. Formative evaluation should be shifted from precise objectives to the occurrences of classroom activities. The units evaluated indicated that the intention of the individuals involved, rather than the goals, objectives and teaching strategies of the unit, was paramount.

Rothe (1979) used a situational-interpretative approach in the evaluation of a social studies program in British Columbia. Along with an extensive discussion of alternative evaluation methods and the theory behind situational procedures, he designed an evaluation method based on existential phenomenology and ethnographic research. The underlying assumptions are that the participants in a situation (students and teachers in an educational setting) interact with the program and each other. This interaction affects their overall interpretation of the values or worth of the experience in unique individual ways. Their meanings can be described following techniques such as interviewing those involved, then interpreting and describing these conversations. The interpretations were based on a model consisting of four areas of being or meaning developed by Rothe and are outlined in Figure 2.

This framework, designed following his investigations into existential phenomenology, was developed to note differences in meaning that both students and teachers gave to the educational situation in which they were involved, as indicated by their responses to questioning and discussions during interviews.

Rothe stressed the areas are not static but interlock with each other; meanings may change as situations change. As transcendence is approached each area subsumes the other area of being. Rothe (1978) defined the areas of being:

> a) Passive Area of Being. This area is farthest from a person's inner being. In this instance a person becomes an object for another person. An individual views his relationship with others in terms of patterns of dominance by avoiding the recognition that he is the creator of his own values. Instead, one perceives 'values' as given in the things and institutions of the situation. A person is not, therefore, the source or creator of his own choices, but finds his meanings outside his inner being.
>
> b) Immediate Area of Being. In this area a person is only concerned about instants of new pleasure and new experience to fight off boredom. Only the present is of paramount importance. The person takes no responsibility for the choice made. The person is only concerned about his personal pleasurable, satisfying moment.
>
> c) Responsible Area of Being. This area is closer to the centre of a person's inner being. A person makes choices and assumes full responsibility for them. A person takes seriously the responsibility of decisiveness and self-determination. He makes his choices with concern for other people's welfare since he realizes other people

are affected by his decisions.

d) Transcendent Area of Being. This area is nearest to a person's sense of inner being. A person experiences an intensified expression of the visible world. He bases his choices on intuitive and spiritual grounds rather than strictly empirical ones. He prizes such quantities as harmony with his fellow man, social justice and religious ideals.

The results of his work were combined with other evaluation methods in order to give as wide an evaluation as possible and a more holistic description of the school situation under investigation.

Interviews were conducted in small groups and selected open ended questions were asked of the participants. The discussions were recorded, transcribed, and interpreted in common sense language then returned to the participants for verification and/or alterations if necessary. The meanings that both student and teachers gave the program were then analyzed in terms of the four "Areas of Being".

Among his recommendations, Rothe suggested that the interpretive evaluation paradigm be used to reveal the common-sense interpretation both teachers and students give to a program. These uncovered meanings may indicate possible reasons for classroom interactions. He also suggested that interpretations should also be returned to teachers and students in order for them to reflect and possibly act upon their meanings and thus create opportunities for classroom change.

It appeared that a methodology involving a situational interpretative evaluation of the snow ecology unit, using observation and participant interviewing, would be a satisfactory approach to take.

CHAPTER 4

THE DEVELOPMENT OF THE WINTER ECOLOGY UNIT

Introductory Comments

My interest in snow as an ecological factor of considerable importance was the result of a problem which arose during the implementation of a revised program of studies in biological technology in the Province of Quebec. My position at the time (1974) was Coordinator (Department Head) of Natural Science Technology at Vanier College (CEGEP) in Montreal. The Quebec Department of Education had, among a number of changes in this three year post secondary diploma program, reshuffled the sequence of some second year courses, including one in ecology and field techniques. The course was scheduled to run from mid January to mid May, in other words, through the winter season. Unfortunately, contemporary ecological field studies seemed designed only for summer conditions.

My initial reaction was, I am afraid, quite typical of most of the biology instructors with whom I was familiar. Field work was considered an activity of any season except winter although, during my teaching at the elementary, secondary and post-secondary levels, student reaction to lab work and field studies had always resulted in what appeared to be a more positive attitude to biological science. Discussions with many colleagues during Biology

Teachers' Association meetings had reinforced this belief. Therefore, to develop an ecology program without student field and lab experiences appeared to negate much of its value. Fortunately, the instructor assigned to the course was familiar with a unique winter boreal ecology program developed at the University of Manitoba by Dr. W. O. Pruitt, Jr., an outstanding boreal ecologist. Information on winter ecology techniques was obtained and some possible winter field activities were prepared. Two considerably successful field sessions, each of three days duration, were held during February and March of 1975. These were met with unusual enthusiasm by the students (age range 17 to 24). Life was discovered to be anything but dormant and the adaptative ability of organisms surviving severe winter conditions was underlined. Winter studies now appeared not only quite feasible, but their general neglect, considering the climate of Canada, was an aspect of biological science in our schools which seemed no longer tolerable. When I made my decision to do research in science education it therefore seemed desirable to include field work and snow ecology as the major basis of my study.

As a preliminary step it was necessary to determine the extent to which the curriculum for high school biology in Alberta emphasized laboratory and field work in its program. The Alberta Department of Education Curriculum Guide for secondary school biology (Alberta Education 1976) lists among others, four key aims for biology education:

1. To enable the student to familiarize himself with his immediate biological world, and to realize the importance of the interdependence of living organisms and the part man plays in this scheme.
2. To develop the ability of a student to carry out successful independent study and learning.
3. To develop sound procedures for biological field and indoor laboratory study.
4. To develop an understanding of and an appreciation for the methods used by scientists; the means and conditions under which science advances; the role of biologists; the importance of accurate and accessible records, and free communication.

Implicit in the objectives is the use of the laboratory, both indoor and outdoor.

If outdoor field work is to be a major activity the conditions under which it is held become significant. An investigation of general climatological conditions during the Canadian school year is quite revealing. They are dominated by one particular season, winter.

Winter as an Environmental Factor

Winter is an integral part of the Canadian environment and one of the basic limiting factor on organisms in this country. Its impact has even defined the school year as typically September through June in all but a very few educational institutions.

An examination of weather records reveals the extent to which the winter season is superimposed on the school year. Snow cover maps of Canada (Potter 1965) indicate median dates of first and last snowfalls and duration of the snow cover. Converting the data to mean values for the Edmonton region, for example, one can expect snow cover to last from October 31 until April 20. Therefore snow is on the ground for more than 50% of the school year. A comparison of temperature and precipitation data based on records of a thirty year period from 1931 to 1960 further emphasizes the extent to which we are living in a cold weather climate (Table 1). In the Edmonton area, somewhat representative of Alberta (except the southwest chinook belt), the addition of freezing dates to those of snow cover extend winter-like conditions to about 84% of the academic year. Such conditions are not confined to the Edmonton area. They range from about 60% of the academic year in Montreal to over 95% in Thunder Bay.

Snow has always been such an important factor in the lives of northern groups of natives that they developed a language to describe the specific physical properties it exhibits at any time, a vocabulary lacking in the English language (Pruitt 1958; 1970). As a result, Pruitt has incorporated a number of expressions from the language of the Kobuk Valley Inuit in Alaska in the terminology of winter ecology in North America (Table 2).

From the biological point of view, winter and snow dominate the Canadian scene. Snow is a part of the hydrologic cycle, serving as a reservoir in the winter and a water source in spring and summer. Glaciers reflect a similar but more long term effect. Snow and temperature extremes play a critical role in the survival of plants and, in particular, animals. The classical work of Formosov (1946) in Russia has heavily influenced recent studies in the northern or boreal regions. He considers snow cover to have such a substantial effect on the lives of plants and animals that it must be considered as a separate factor from climate. He has also devised a special nomenclature for the relationship between animals and snow conditions. Chionophobes are unable to adjust to snow conditions (many of our "summer" birds); Chioneuphores, such as voles (Clethrionomys sp.), shrews (Sorex sp.) and moose (Alces alces), can survive in snow regions Chionophiles, such as caribou (Rangifer tarandus) and the snowshoe hare (Lepus americanus), possess special adaptations for snow and are limited completely or almost completely to snow regions (Formozov 1946). Due to the insulation properties of snow, many of our small mammals with poor surface area-volume ratios are able to survive in a subnivian (under snow) environment, and remain active all winter long. Since small mammals are the food source for a number of predators, these predators are able to survive under conditions which would otherwise be impossible. Because the insulation effect of snow is directly proportional to its depth and density (Elsner and Pruitt 1959), the varying snow conditions, such as total accumulations, drifting, melting, whether in open areas or forest, determine the extent to which a population of organisms can survive.

Snow also has an impact on plant life, much of which is also protected by insulation. Large plants, such as trees, with an accumulation of snow (qali) on branches and/or leaves may become seriously damaged or even die (Gill 1974). This is believed responsible in part for succession patterns in the boreal forest (Pruitt 1958; 1970; 1975), which comprises the greater part of the forested area of Canada (Rowe 1972). The moderate subnivean temperatures protect the roots and stems of low growing perennials and biennials. Snow may be required to activate many seeds.

Because Canada is a northern country the tremendous impact of winter on our organisms places us in a unique environment shared by few other countries. Yet, to quote Pruitt (1975), "In the literature of the sciences that ought to be concerned, there is little to suggest that snow is a major element in the environment of life". An investigation of some of the basic general biology and ecology texts used in high schools and colleges reveals a dearth of information on northern ecosystems. This is probably due to the American origin of most textual publications in North America where, other than in Alaska, the direct effects of winter are not normally of major concern in the more populated areas. Examination of a number of recognized ecological reference books including Oosting (1956), Benton and Werner (1958), Odum (1971), Colinvaux (1973), Smith (1974), Whittaker (1975), Richardson (1977), Maxwell (1980) and Remmest (1980), reveals that "winter" and "snow" are rarely mentioned.

It would thus follow that Canadian high school biology curricula, heavily influenced by research, development and texts from south of the border should also reflect this lack of emphasis on the limiting factors of winter and the adaptations of organisms to Canadian climatic extremes, regardless of their otherwise high quality. An investigation of the texts produced in the United States and recommended for the ecologically-oriented Biology 20 program in Alberta (Table 3), substantiates this belief.

In a monograph concerning biology education in American schools, Paul Dehart Hurd (1981) commented on teacher resource materials in secondary school biology courses.

> The basic classroom instructional resource is the textbook. It is the "answer place" for teacher questions, almost all of which come from the text and concern terminology and definition. More than 90 percent of 12,000 science teachers surveyed said that texts were the heart of their teaching 90 to 95 percent of the time. The textbook is both the medium and the message, and most teachers do not stray far from its organization and subject matter.

Since both teachers and students rely so heavily on texts which largely ignore the season, the chance of winter ecology being a component of our biology program appears limited.

Tretiak (1973) states that although winter is exclusive to the school year, little use is made of it and that field studies are confined to the spring and fall. Other than a natural reluctance to face the cold, a lack of information on snow and winter ecology is probably one of the prime factors resulting in the above. The impressive growth and renewed interest in outdoor activities in winter, such as skiing, snowshoeing and backpacking, indicates a growing enthusiasm towards coexistance with our climate. There is a distinct need for research and development into this area of study. Biology curricula in this country definitely require an orientation toward our own unique conditions. Too many decisions affecting the future of Canada require its citizens to have at least a layman's knowlege of boreal conditions.

Research on Field Studies and Winter Ecology

An examination of the literature on snow and its effects on organisms quickly revealed a paucity of information available on the ecology of winter in a form usable at the high school level. A major aim of the research thus became an attempt to develop, then evaluate, a series of individual student winter ecology projects for use in the senior high school biology program. Ecological principles were a major part of the Biology 20 program and the required individual student research project appeared to be a likely vehicle for snow ecology investigations.

A number of graduate studies had been conducted on the topics of biology projects, laboratory activities and the use of live animals in the Alberta school context. These were examined in order to provide insight into the laboratory type of experience so that any development of a winter ecology project could reflect the needs and expectations of both students and teachers.

Jacknicke (1968) found that lack of knowledge of available species resulted in a minimum use of local freshwater organisms, even though teachers recognized the motivation value of the immediate environment.

Dyke (1970) noted the motivational value of live animals in grade eight sciences but at the same time a lack of teacher familiarity with the source and handling of feral mammals.

Anderson (1972) examined the use of projects in secondary school biology. A major problem, particularly in rural areas, was a lack of reference materials. Teachers reported increased enthusiasm among student project participants. A list of project topics in use revealed 170 separate investigations of which 22 were specifically ecological but only sixteen were definitely of an outdoor nature. Winter projects were not mentioned.

Darroch (1972) examined the extent to which the project selected by Biology 30 students reflected the material in Unit II, Current Biology Problems. His study revealed that many teachers were unfamiliar with related project topics. Approximately 93% of the projects did not involve the laboratory. He suggested that there was a distinct need for teachers to become more familiar with the local environment, and that resource materials, including field trip ideas, seemed necessary.

Paetkau (1973), after an investigation of the secondary school science curricula biology component, identified where ecology projects would be most suitable. Following a survey of teachers of grades seven, ten, eleven, and twelve, a distinct demand was felt for assistance in designing ecological projects. He noted that teachers preferred small groups or individual projects and preferred to run them in autumn and spring rather than in winter. Among his recommendations, the development and dissemination of materials relevant to ecology projects had high priority. Suggestions for winter use were given, most involving indoor laboratory studies.

Franz (1974) developed a series of projects on the use of insects in behaviour studies for teaching in south-western Alberta. He found an inefficient use being made of local organisms and that project guides, providing assistance to teacher and student alike, were definitely required. A feeling among biology teachers for the value of projects in the development of process skills and science attitudes, especially by the provision for active involvement and individualized instruction, was clearly stated.

General conclusions to be drawn from these six studies suggest:

1. Projects, in some form, are in use in a majority of biology programs.
2. Teachers generally are not aware of the wealth of material available, particularly at the local level.
3. Teachers desire support materials and suggestions for ecology projects.
4. Teachers consider projects to be of benefit both from the process skill development point of view and the motivational power attributed to working with living things.

A further literature search revealed that a limited number of winter ecology studies had been attempted or researched.

Bullington (1959) organized a winter field experience course for prospective high school biology teachers at Northern Illinois University. From high school texts the students prepared lists of subject matter activities which could be taught in the winter. The group spent three days in the field testing their ideas, with some considerable success. However, snow was not a factor in the studies nor was it on the ground at the time of the winter camp. Murphy (1970; 1971) suggested a number of winter activities, some of which involve snow. Few details were provided and no evaluation was attempted. Tretiak (1973) prepared a handbook for the Manitoba Department of Education which described the effects of winter on organisms. Tretiak suggested a number of activities which could be incorporated into the school science curriculum to illustrate some of these effects.

Phillips and Watson (1976; 1977) described a snow ecology unit and activities they devised and presently teach at the grade ten level in Winnipeg, Manitoba. A number of projects are currently in use and are reported to be quite effective although no formal evaluation has taken place. High student enthusiasm was noted at all times. Collins (1976) developed a winter ecology module for the Grade 5 and 6 levels in Newfoundland schools. Although a number of activities were suggested, few involved the outdoors and most of the material was of a classroom nature. There was a positive reception of the unit by both teachers and students, particularly due to its emphasis on Canadian and local organisms and environmental conditions. Picker (1980) developed a series of ten secondary level winter ecology experiments designed around the 1973 B.S.C.S. Green Version ecology conceptual scheme. Several laboratory and field techniques were integrated into the activities. The effectiveness of the program was evaluated by empirical methods. The programs ran from January 1 to March 15, 1978 in five New England separate schools. Six teachers and more than 200 students were involved. Data analysis showed significant cognitive gains ($p<0.0001$), significant positive gains in attitude toward the environment ($p <0.0001$) and increased involvement with the winter environment. The conclusion reached strongly indicated that the units were teachable, inexpensive, nonsexist and successful in involving students. Student enthusiasm appeared to increase during the program.

Developing the Snow Ecology Unit

When the structure of the Alberta biology curriculum was considered along with the apparent use of the laboratory by Alberta teachers an opportunity became evident for the development, implementation and evaluation of a snow ecology unit. The Biology 20 program was particularly suited to this purpose since it was ecological in theme and required a mandatory student ecology project. Teachers definitely considered that projects were of benefit to the students but requested project topic suggestions and support materials. Many were also unaware of the wealth of local materials and sites for investigation. A snow ecology unit designed to meet these needs appeared to be a worthwhile undertaking.

Preliminary work began on the preparation of a series of individual snow ecology investigations. The intent was to reduce the concerns of teachers for field work by providing them with modules which could be easily handled by the students and would require little previous background on the teacher's part. Potential topics were selected by a further review of research articles in boreal ecology and the few activities which had been used successfully in school settings. Each module was to consist of a sequence of investigations which would illustrate basic winter ecology principles, the emphasis being on snow as an insulating material. Fifteen specific investigations were outlined. Of the potential topics, six were selected for further development as they appeared to be workable in the variety of environmental situations, both urban and rural.

According to Allen (1971), long term projects may lend continuity to laboratory studies and cast students in the role of biologists. The discussion of results during and after the study permits comparison of results, the identification of still unanswered questions, suggestions for further study and often the formulation of basic plans for extended work. Furthermore, Allen suggests that a laboratory activity should include:

1. An attempt to create an atmosphere of research and discovery.
2. Involve research reading.
3. Illustrate, without supplying answers, the basic biological principles involved.
4. Require the data collected by students be viewed by all students.
5. Require a written record of the work, following an acceptable format.

As mentioned earlier in this chapter, Franz (1974) had developed a series of student projects which investigated insect behaviour. He based these investigations on the following major objectives:

1. The development of deeper understanding of an appreciation for living organisms.
2. The development of skills in scientific thinking and problem solving.
3. An encouragement of the attitudes of curiosity and enquiry.
4. Provision for the practice in the methods of scientific research and proper scientific reporting.
5. The provision of content that is of special interest and relevance to the student.

As a result of his investigation Franz noted that both teachers and students required assistance in obtaining suggestions for experiments, background information on each topic and help in the organization of the lab investigations. Self contained investigations appeared to be effective. His final lab design included the following major headings:

Theory (background)
Materials
Procedures
Interpretations (questions for discussion)
Extended exercises (for further study)

He stressed that the topics to be investigated should be within the capabilities of the students and within the resources of the school. He found that students could construct simple but effective home-made equipment to reduce costs.

Kennedy (1977) recommended the same basic laboratory design and stressed accurate recording and discussion of data, within the students' own lab groups as well as between other members in the class. The excitement of a successful investigation appeared to be highly desired by students.

The Biological Science Curriculum Studies organization in the United States developed one of their programs around laboratory investigations. The B.S.C.S. Black version, which emphasizes laboratory-oriented inquiries, attempts to utilize previous biological experience, involves the methods of scientific study, and instructs in ways of handling data and in using scientific literature.

Baker and Allen (1971) note the basic "pattern of deductive logic in every scientific experiment or observation" and that there should be a continued stress on this pattern to the students. The prediction of possible results based on some hypothesis is a major aspect of the scientific approach and the predictions are tested by experimentation. In an inquiry-oriented investigation the student is exposed to the pattern of logic but is not actually being a research scientist. They consider that a large collection of data is of limited value unless it is arranged in some way to show important relationships. Tables and graphs aid in data analysis.

An examination of the laboratory manuals used in high school biology revealed a standard design, consistent with the traditional approach to which most science teachers, including myself, have been exposed in university science courses. These main headings are variations of those used by Franz. Additionally, contact with many of my colleagues in both Canada and the United States provided some design aspects which I attempted to incorporate into my snow ecology investigations. These included a desire for descriptions of possible activities which would extend for more than a class period, a time line for their completion, materials required, marking sheets and student reports requiring the use of graphs and tables. It should be noted that the previous examples, and especially the notion of reporting, is based on a re-constructed logic and that it is asking students to think in a particular way.

Using these observations on laboratory activities plus the experience gained as a classroom teacher, preliminary drafts of some snow projects were prepared during the summer of 1977.

Projects require time to complete and classroom time is limited. To overcome this problem and make the use of the snow projects more desirable, they were organized so that the student could run them if necessary at home on his/her own time. Since most teachers have little background in the use of the local environment in biology teaching, the projects required a minimum of teacher preparation and participation but provided them with key information on the topics. However, before beginning the projects, teachers were to be presented with articles and books on snow ecology to provide them with sufficient background information to advise students and evaluate their work. The projects were written in the traditional laboratory style, a form most familiar to science teachers. The purpose(s) of the particular activity was (were) stated, a method of study described, instructions on recording the data collected (results) and questions posed to aid the student in examining, analyzing and discussing that data. Because the projects were designed for individual student use, considerable background material was included. A separate booklet was prepared with a glossary of snow ecology terms, instructions on data recording techniques, graphs, the construction and use of equipment unique to snow ecology field work, required mathematical calculations and other items of potential use to the student. All students were expected to complete two core activities, then select one further activity based on personal interest and the local environment. The purpose of the core projects was to introduce the student to snow measurement techniques which would establish some basic principles of the abiotic effects of snow. They were designed as guided enquiry activities in that there was no indication given of the possible results of their work. The students were also asked to predict the possible results of their investigation before commencing. The principles established would be the basis of the subsequent investigation. The core activity and the additional project topics are_listed in Table 4.

Brief outlines were prepared on other topics students could pursue, if interested, and are listed below.

1. The effect of temperature on red squirrel activity.
2. The influence of the qamaniq on the distribution of small subnivean mammals.
3. The effect of slop aspect on the distribution of small subnivean mammals.
4. Grouse snow burrows.
5. The impact of overwintering on the size of a small mammal population.
6. The effect of winter on bud development in plants.
7. The effect of snowmobiles, snowshoe and cross country ski trails on the pukak layers.
8. The influence of "edge" on small mammal distribution in winter.
9. The habitat of subnivean mammals in winter.
10. The relationship between the surface activity of small mammals and snow depth.
11. The effect of microtopography on the distribution of small subnivean mammals.
12. The preparation of a reference collection of small mammal scats.
13. The effect of quali on vegetation.

All projects were developed from the available literature on snow ecology and tested to see if they were possible with a minimum of sophisticated procedures and expensive equipment. Test locations were in the city (my back yard) and on a farm south of Edmonton. Homemade measuring devices were utilized where practical. Although all the projects proved possible, many, especially those in the second group, were not practical for most biology classes unless they were conducted in a rural situation.

After returning to full time teaching of biology in 1977, I had the opportunity of testing the units in the classroom situation on a limited basis. Since I was instructing Biology 10, a few students elected to use snow units as part of their required project. The students appeared to have no major difficulties carrying out the work and were quick to point out areas of difficulty. This permitted further revision of the projects and preparation for formal field testing. More extensive field tests of most of the basic projects occurred during the winters of 1978 and 1979. Conditions were abnormal. Little snow fell and temperatures were above average. Nevertheless, enough information was obtained from both personal observation and student comments to judge the practicability of the core projects and most of the basic optional units. Students readily described some of the difficulties encountered with the units. These included the reading level of the materials, organization and sequence of individual investigations, equipment use and comprehending instructions on both procedures and data analysis. With revision the units seemed feasible as the basis of the individual project portion of the Biology 20 program.

The development and revision of the projects was time consuming and often frustrating. The instructions for simple activity which appeared clear to the writer had often proved confusing to the students during field testing. Since a change in weather could affect the results obtained, either provisions had to be made to allow for the unexpected or the activity dropped entirely. The many suggestions made by students and teachers eventually led to a reasonable final product. Throughout the development, however, one thing became quite clear. The activities did work and both teachers and students expressed considerable satisfaction with them.

The next consideration was the manner of evaluating the effectiveness of snow ecology activities in the high school biology program. This posed a serious problem. Empirical research designs involving statistical analysis did not seem appropriate for the type of information I wished to uncover. Since snow as an abiotic factor in biology programs was rarely mentioned, pre- and post-testing the students on knowledge gained would reveal little. It was decided that the thrust of the evaluation would be an attempt to reveal the meanings the snow unit had to the students and teachers, using emic-evaluation techniques. This would also provide information on the value of the laboratory experience to the participants and therefore information on its worth in a school situation.

The method of study now identified, new problems arose. Since teacher participation was a necessary part of the evaluation process, the snow projects had to be redesigned into a classroom unit of short duration so that the interaction between students, teachers and the specific activities could be recorded. During 1980 the unit was reworked so that it would be completed in a two-week time span.

The design of the final version also took into consideration two basic problems for the classes that would participate in the evaluation. The teachers would not be familiar with the topic yet they would be asked to give up two weeks of teaching time to run the unit. As well, because of semestering, the Biology 20 program was reduced from the recommended 75 hours to 62.5 hours, placing additional pressure on both teachers and students. Simplifying the unit to cut back on teachers' preparation time and correcting load was necessary, resulting in the modification of some items.

The final unit consisted of two student booklets (Appendix A), a teachers' guidebook (Appendix B), and a set of data recording forms and lab report sheets for each student (Appendix C). Allan (1979) had suggested fifteen characteristics of a good laboratory investigation. These were used, in part, as a guide during the final revisions:

1. Does it involve a biological principle or concept?
2. Does it involve a problem or situation concerning life?
3. Does its study involve living specimens or a life situation?
4. Does it encompass the broad purposes and goals of the course?
5. Does it allow the student to engage in the investigation on his own?
6. Does it allow for every student to be an active participant?
7. Does it require a minimum of technical skill and material, in accordance with the student's resources and maturity level?
8. Does it allow student to employ scientific methods in the lab (careful observations, precise measurements collection and analysis of data)?
9. Does it encourage students to form their own conclusions about the significance of the data and of the investigation?
10. Does it have student interest and appeal?
11. Does it have meaning and relevance to the student in terms of the topic under consideration?
12. Does it allow for the primary study to be extended beyond the planned scope?
13. Does it have integrity as an investigation in that it

poses a problem for solution that is not described in the textbook?

14. Does it have simplicity of design that offers students a reasonable assurance that they will succeed at discovery?
15. Does it have order that proceeds according to a sequence that students can follow?

The student activities were designed to be done in two parts. Part one involved a "guided" enquiry approach to the importance of snow as an insulating material. Students were provided with situations, required to make predictions, then sent out to collect data to confirm or reject their predictions. Experience had indicated that the vast majority of students were unfamiliar with the major concepts of snow ecology being investigated. Nevertheless, they were expected not only to collect data but to reveal some of these concepts by analysing their results. With the basics completed, part two involved students in reading original articles on snow ecology. An assignment followed the readings to ensure their thorough reading of the articles, failure to read (or to read adequately) being an ongoing problem among students at all levels. A final outdoor activity required the students to investigate the environment of subnivean organisms while at the same time constructing a snow shelter, a practical application of the principles learned.

Recording sheets were developed to reduce preparatory time and simplify student data collection under what could be rather difficult conditions. Laboratory report sheets were also designed to focus the students' attention on methods of presenting data in a recognized format. Specific questions requiring basic data analysis leading to some type of conclusion was included. The students were expected to present their own individual reports and assignments although they may have worked as a member of a group. Pooled data were required for certain measurements and averages were to be calculated to compensate for experimental error.

Equipment made by the students was also to be utilized to emphasize the effectiveness of simple apparatus in a laboratory situation. The outdoor investigations would also require teamwork, particularly under the conditions winter could provide. A wide variety of psychomotor and process skills were required.

The teachers' guidebook listed the concepts to be developed during the unit. Also provided were time lines for the activities, suggestions for presenting each, a marking grid and a sample of possible answers to the questions asked the students as part of their data analysis.

Although complete satisfaction with any project design is virtually impossible, the redesigned unit appeared ready for classroom trial. The final judgement on the worth of snow ecology and, in more general terms, the laboratory experience, was now in the hands of the teachers and students who would participate in the activites.

CHAPTER 5

METHOD OF STUDY

Some Preliminary Considerations

Ethnographic techniques attempt to gather data which describe social situations such as the classroom. This type of study incorporates participant observation, interviewing and qualitative analysis to gain an understanding of participant behaviour. Since the data are qualitative there is not available the prescribed formulae or precise statistical treatments of the qualitative techniques. Werner and Rothe (1980) emphasized the problems inherent in situational interpretative studies.

> The procedures of ethnography are not as clearcut as are some other research approaches used for collecting and analyzing information. Fieldwork is sometimes "messy" in appearance because methods may have to be defined and changed *in situ*. Fitting into the time schedules of other people, and being dependent upon good relations with them for entry and acceptance, require patience on the part of the researcher. Willingness to listen, openness to frequent change, ability to try various methodological avenues, and interpersonal skills are a part of the ethnographer's toolbox as they are for any researcher in the social sciences.

They also defined the task of the evaluator as uncovering the relevance and meaning which a program has for the individuals involved. This not only involves students and teachers but includes administrators and parents. Evaluators, by asking questions, interpret the common-sense meaning the actors make of a program, their perceptions, viewpoints, the relevance of the program for them and whether it is appropriate to their school situation. As a result any program has as many personal definitions and relevances as there are teachers and students participating in it. Depending on the specific situation and the evaluation's purpose, the methods of defining and collecting information will vary in order to uncover and describe the interpretations, criticisms and standards of worth brought to the program by the actors within it.

George Psathas (1973) suggested three tests for ethnographic validity:

1. a) Are the findings faithful and consistent with the experiences of those who live in the situation?
   b) Are the findings faithful representations, descriptions, accounts, or interpretations of what those who ordinarily live those activities would themselves recognize to be true?
   c) If second order constructs were translated into first order constructs to which they refer, would the observer's report be recognized as a valid and faithful account of "what the acitivity is really like?"
2. Armed with "only" the knowledge gained from reading the account presented by the observer, would

someone else be able to understand what he was seeing when confronted with the actual lifeworld reality of the events described?

3. Can the reader become a player after having read the rules?

The descriptions must make sense to the actors and thus the validity is inherent in the congruent meaningfulness of those "involved".

Werner and Rothe (1980) classified the methodology used for collecting and analyzing data in situational - interpretative studies into three categories: pre-entry, entry and follow-up procedures.

Pre-entry concerns itself with the initial discussions with the organization who desire the evaluation. Since this type of research is conducted in situ, group acceptance of the researcher is critical and entry must be planned carefully. Clear descriptions of the research techniques to be used must be provided.

Entry involves data collection. The exact methods followed depend on the purpose of the research and type of data to be gathered. The major problem to be overcome is to fit into the school routines with minimum disturbance. There must be continuous negotiation with the participants, since their private domains are being invaded.

Follow-up procedures involve the analysis of the data, which includes preparation of descriptions of the viewed activities, validation of these descriptions and preparation of the final assessment of significance to the organization involved.

In order to validate the data collected when using interviews, descriptions are returned to those interviewed, and if disagreements occur, revisions made. The end result should be a series of final descriptions which match as closely as possible both the researcher's and participant's understandings of them. Whenever research involves a record of student and teacher responses to a real in-school situation, anonymity must be guaranteed to protect the identity of the individuals involved. Therefore, in this study all teachers, students, schools and communities have been given fictional names.

Negotiation of entry and entry itself posed somewhat of a problem in this particular research study. The teachers were asked to introduce a new unit of study with which they were not familiar. Their background in the subject matter was, at best, very limited. Fortunately, the snow unit fit into the theme of the Alberta Biology 20 program, with its emphasis on ecological interrelationships. The unit therefore promised to be a logical part of the course and would keep disruption to a minimum.

Since the activities involve the study of snow, snow must make an appearance. Below freezing temperatures are also required for best illustrative results. This limits the effective time for the research to the months of

December, January and February, proving to have been a significant problem in field trials of the investigations. In schools December is interrupted by Christmas holidays. If the school(s) involved is (are) on a semester system, the end of the first semester, including its final examination period, occurs in the last half of January, further reducing the time available for the introduction of the unit, designed to occupy two consecutive weeks. The second semester, with its new groups of students and the often redistributed courses and teaching load of the instructors, commences the first week of February. February is also interrupted by Teachers' Convention. Careful negotiation of entry into the school is indeed essential.

Location of the Study

The study was carried out in a County located in central Alberta and adjacent to a large urban centre. The county has a population of approximately 50,000 persons, of which 60% live in a suburban environment and the remainder on acreages or farms. Two of the senior high schools in the county were involved in the research. The county was selected because of its proximity to the researcher and his familiarity with the system and many of its staff and students.

The Interview as a Research Technique

Cicourel (1964) noted that students of social research recognize that interviewing may elicit or stimulate a wide range of responses. It was to be a major concern of this researcher to obtain, by means of interviews, an insight into the personal meanings given to the biology laboratory experience by the participants in the snow ecology unit.

The interview process was defined by Stewart and Cash (1974) as that of dyadic (face-to-face) communication with a predetermined and serious purpose designed to interchange behaviour, usually involving the asking and answering of questions and not occurring in isolation. Gordon (1980) defined interviewing as simply talking to people in a communication dyad.

Stewart and Cash (1974) suggested that a number of factors affect both interviewer and interviewee behaviour. Non verbal actions such as body movements and facial expressions may influence responses to questions. The absence of interruption during an interview tend to increase both the number and length of responses by all parties. The leaning forward of the interviewer evokes more positive response from the interviewee. Verbal actions include open-ended questions and responses which permit more interpretation and larger responses. Interviews between individuals stimulate a greater verbalization than group interviews. In general, the interviewee response tends to be double the length of the questions asked. The atmosphere of the interview surroundings, such as room size, colour and furnishings, affects interview results. Interpersonal attraction is critical in the interview situation. Trustworthiness must be established since the responses may reveal information which some authority may examine. In-depth responses occur only if a good interpersonal relationship is established.

The tape recorder is considered to be essential to the interview technique (Stewart and Cash 1974). It can record all that is said and how it is said. The interviewer can relax and concentrate on the questions and answers. The recorder may also pick up extraneous noises and conversations or may record nothing. Stewart and Cash stressed that note-taking may interfere with the communication climate; for example, eye-to-eye contact. The interviewee may watch the notes being taken and become distracted from the job at hand. Note-taking also requires high-speed writing. The primary purpose of the information-gathering interview is to acquire accurate, adequate data in the shortest possible amount of time.

A warm up period is needed in an interview before valid materials are obtained (Gordon 1980). Questions can be arranged in a logical sequence to allow for this to happen. The language used must be in terms of the group being interviewed. Gordon (1980) suggested that an interview guide be prepared to help direct the interviewer toward the objectives of the interview. It should provide an outline of topics but not necessarily the sequence. Freedom of movement within the interview situation must be possible. Three general objectives of the interview are noted. The questions must be designed to get at information, thus relevance is a necessity. Validity and reliability depend on maintaining generally good interpersonal relations with the respondents.

Gordon (1980) noted that time may be an inhibiting factor. For example, as the time approaches for the respondent to attend to another activity, interest and concentration may be lost. If information could threaten self-esteem, an ego threat occurs. Because there is a natural fading of memory, forgetting can be a factor. Respondents must be willing to participate. The time and place of the interview may influence responses and willingness to participate. The purpose of the interview should be clearly explained and anonymity provided. Descriptions and explanations should be in terms the respondents can understand.

Gordon (1980) also commented on the tape recording of interviews. Noting that the more complex the information, the less the interviewer should rely on memory. This would also apply to the rapid flow of relevant information. The more the exploration for unanticipated types of responses the more the tape recorder should be used. There appears to be very little apprehension on the part of the interviewees in the presence of a tape recorder. If precise statements are of significance, the recorder is invaluable. Gordon concluded with the statement that the interviewer can devote attention to the questions and answers and concentrate on obtaining optional interpersonal relations. The use of the machine must be explained to the interviewee, then kept out of the line of sight of all participants and ignored once the interview commences.

Cicourel (1964) stated that the interview as used to test specific hypotheses about substantive matters "strains conventional measurement because the measurement technique forces us to assume 'identical' interviews with 'identical' questions and responses". He also noted that it is "impossible to anticipate all possible contingencies much less expect the interviewer to contend with them adequately on each occasion", clearly stating that "it is not possible in the sense of the classical experiment of exploring the same conditions to the same sample of subjects in identical fashion with complete controls". However, some controls exist by knowing in part what to expect and recording what actually happens.

Throughout the interview the previous points were taken into consideration. In order to concentrate on the responses, to modify or expand on questions as necessary and to appear concerned with the discussions at all times, no attempt was made to write comments or notes of any kind. Although this meant that facial expressions and shrugs, often indicative of special meaning, were unrecorded, it was felt that a more relaxed and natural conversation would result. Common-sense language was used throughout the interviews. As a former teacher at the school, the students either knew me by sight or word-of-mouth. A natural though limited rapport was already in existence. The same was true for the participating teachers.

Pre-entry

In order to obtain sufficient data on the meanings and values ascribed to the snow ecology unit in particular and laboratory activities in general, it was hoped to involve at least two Biology 20 classes.

Before contacting any participants, it was necessary to develop the basic method of approach to be used during the evaluation period so that potential teachers, principals and school boards would be aware of the research. Data on the meanings given to laboratory activities by both students and teachers, using the designed snow ecology unit as a vehicle, were to be collected by means of recorded interviews. Five students from each class as well as the classroom teachers were to be interviewed. The students would be selected by the teachers based on having completed the unit and being willing to participate. Anonymity would be protected. The researcher would transcribe each interview, omitting unnecessary repetitions, pauses, etc., and the responses would then be described and interpreted. It was intended to return these first descriptions as soon as possible to the interviewees to read and for reaction to the interpretations. If there were any disagreements, further discussion and immediate revisions would occur. Following validation of the interview interpretations, the data would be incorporated into the research thesis. The students would be interviewed in groups and the teachers on a one-to-one basis.

Interview questions were developed as guidelines in order to obtain information and reactions to the snow ecology unit specifically and laboratory work in general. Questions directed at the unit would often lead to a more general discussion of the laboratory experience, not only in biology but the other sciences as well. The use of phrases such as "why", "in what way", or "explain" were able to extend an apparently simple question so that it was able to probe into the possible deeper meanings the experience had for the individual. The questions were organized into separate groups for teachers and students. It must be noted that the sequence of questions does not indicate the sequence in which they were asked. Since they were to serve as a core for discussion, their order or precise wording could not be predetermined. In many instances during the actual interview, answers were obtained without recourse to specific questions while discussing some other item. Nervousness on the part of the interviewer, student or teacher reaction to the questioning and time constraints on interview length were factors which also influenced the questioning.

In order to aid in the development of questions for evaluation, discussions were held informally with twelve members of the staff of Alpha High School during the school year 1980-81. The individuals represented the administration and most subject areas. They were asked to consider the type of question they would want to be asked if a program they were teaching/supervising was to be evaluated by an educational authority in order to decide if the course should continue or be dropped from the curriculum. From these suggestions, plus reference to key areas in the winter field activities themselves, a list of basic, open-ended questions was developed for the interviews with the teachers involved in the study:

1. Describe your teaching background and experience in the sciences.
2. Describe student response to the snow unit.
3. Were the objectives of the snow unit realistic, worthwhile and attainable? Explain.
4. Were the materials presented in a logical and understandable manner? Explain.
5. Would you suggest any changes or improvements to the unit? Describe.
6. How did you introduce the unit to the class? How closely did you follow the teaching guidelines for

the unit?

7. Was the unit appropriate for Biology 20? Why or why not?
8. Did there appear to be future applications of the concepts learned? Explain.
9. Were the evaluation guidelines satisfactory? Explain. How do you usually evaluate laboratory work? Why?
10. Could the laboratory materials have been taught as classroom material rather than in a laboratory situation? Why or why not? (value of laboratory work)
11. What were your overall reactions to the snow unit? Explain.
12. Were the resource materials/equipment available and satisfactory? Why or why not?

The questions designed for the student interviews attempted to bring out their views or attitudes toward science in general, laboratory work in science and reactions to the snow unit as a laboratory activity.

It was hoped that analysis of their answers would provide insight into the meanings and values the laboratory had for the students and would thus aid in evaluating not only the effectiveness and worth of the snow ecology unit but the laboratory enterprise itself: (The core series of questions are listed below:)

1. What science courses have you taken in high school?
2. Did any of your science courses have laboratory work? Describe some of the laboratory activities.
3. Describe some of the activities involved in the snow ecology unit.
4. What is your opinion on the organization and sequence of activities in the unit? Why?
5. Did you experience any problems with the equipment used in the activities? Why?
6. What was your reaction to the assignment and results/discussion sheets? Why?
7. Was data gathering a problem? Why or why not?
8. Do you have any comments, suggested changes? Why?
9. Do you feel you have gained anything of value from having done the unit?
10. Have you discussed or used any of the material from the unit outside the classroom? Why?
11. Could the concepts investigated have been taught in the usual classroom setting just as well? Why or why not?
12. Was the evaluation of your work by the teacher a fair evaluation? Why?
13. How do you see laboratory work being evaluated? Why?
14. Is laboratory work really necessary in a science course or could the information be learned as effectively in regular classroom activities?
15. Do you have any further comments on the unit or

laboratory activities in general?

If possible, it was decided to involve three classes of Biology 20 students. Two classes were to be selected from Alpha High School and a single class from Beta High School. Alpha High provided a number of Biology 20 sections taught by different teachers. The class at Beta High was to be taught by the researcher.

Since the researcher was a former staff member at Alpha High, preliminary discussions with the school administration and biology teachers were no problem. Formal contact was made in June 1981, when tentative teaching assignments were available for the 1981-82 school year. The aims of the research, the design of the ecology unit and the research method were discussed with two of the Biology 20 teachers who had classes scheduled at a time that appeared convenient for purposes of the study. Both teachers were quite interested in the research problem and indicated that they were definitely willing to participate. Contact was then made with the principal of the school, the research explained and the teachers' names submitted for his consideration. He fully endorsed this preliminary submission and suggested that I approach the shcool board for official approval in the fall.

During the summer of 1981 final adjustments were made to the snow ecology unit and a tentative package of materials assembled. A potential problem was duly noted concerning the time available to complete the data-gathering.

Rothe (1979; pers. comm. 1981) had indicated that the time required to transcribe interviews from tape recordings and write up descriptive interpretations took an inordinant amount of time. To have classes run the unit at the same time would result in a logistic nightmare. It was decided that one class would do the unit in December 1981 and a second group in February 1982. Interviewing for the first group could be completed before Christmas break with transcriptions and interpretations finished during the holiday period. This would allow for validation of these descriptions in January and the completion of the data collection before the next class would begin the unit. The load would thus be more equitably distributed. As I was scheduled to teach a section of Biology 20 the decision was made to also involve this group in the evaluation. Not only would the population size be increased but interviewing arrangements would be easily accommodated and the opportunity provided to view the situation first hand and to record personal observations and reactions. It was hoped that a group of five students per class plus the two classroom teachers would be interviewed about their reactions to the unit and the laboratory experience.

In September 1981, the teachers and principal were contacted again for confirmation of their participation. They were all looking forward to the experience and were most supportive. A tentative schedule for introducing the unit was prepared, based on the teachers' finalized instructional assignments.

In October the assistant superintendent was contacted by phone to enquire as to the Board of Education's preferred method of approach in a research situation. He suggested that, in addition to the usual special request forms submitted to the board by the Department of Secondary Education at the University of Alberta, he desired a personal letter which outlined the research aims, proposed method of study and the estimated time-line. Following this conversation the letter was sent to the assistant superintendent, and at the same time, formal school board approval was requested by the Department of Secondary Education. The Board reacted favourably and in late November granted permission to proceed with the research. The board requested that the anonymity of all schools and persons be respected.

The teachers were informed that their involvement had been approved. Because of the time involved in interviewing, transcribing and validating the transcriptions by those interviewed, it was decided to run the unit in one of the two classes in December 1981 and the other shortly after the start of the second semester in February 1982. Because of her teaching assignment, Mrs. Jones' class was to try the unit before Christmas, during the second two weeks of December, and Mr. Smith's during the middle of February, immediately following Teachers' Convention. The researcher's own class would also participate, at the same time as Mr. Smith's.

A copy of the two student instruction booklets (Appendix A) was provided to both teachers in November for familiarization. Three weeks prior to introducing the unit in their respective classes, the teachers were given the materials listed below:

1. A list of the concepts to be developed and a suggested marking grid (Appendix B).
2. A complete set of booklets for each student.
3. A supply of data recording sheets for each activity (Appendix C).
4. A supply of assignment and laboratory report (result/discussion) sheets (Appendix D).

Items 3 and 4 were of sufficient numbers to provide one complete set per student. Extra copies of items 2, 3, and 4 were provided in case of unexpected shortages.

The items were examined and discussed in detail, and the expected time-line for the unit was explained. Teaching strategies were suggested and possible problem areas explored. Questions raised by the teachers were answered. The teachers were encouraged to follow the guidelines as closely as possible but to make modifications if absolutely required. Weather conditions were perceived as having the greatest impact on the operation of the unit.

Both teachers appeared quite enthusiastic and anxious to get started. Personal and telephone contact was maintained prior to and during the presentation of the unit in case further instruction clarifications were required or unforseen difficulties emerged.

Discussions were also held on the method of selecting students for interviewing after the unit was complete. It was agreed that the teacher would select those students who had completed all the activities (not necessarily all the hand-in assignments) and were willing to participate in an evaluation of the unit. Five students was suggested as a desirable group number for interviews. The aims and organization of the teacher's interviews were also reviewed. The principal of the school was kept informed of the status of the research and was also given copies of all the materials to be used in the classroom.

Because the classes were not all to be taught the unit at the same time of the school year there was a strong possibility that the outside conditions could greatly differ. Since it was impossible for the researcher to be present during the time the students from Alpha High did the field work, that information had to come entirely from the student and teacher interviews. However, the class at Beta High was being taught by the researcher. This provided a unique opportunity to follow the day-to-day events in the snow unit, noting personal, student and general class reactions. Students were also to be interviewed. While each classroom situation would be in some respects a special situation, the meanings given to the snow ecology activities by the variety of students and teachers participating should give a more realistic view of their experiences.

Student and Teacher Interviewing

Information on the meaning and worth of the laboratory experience was gathered from both teachers and students by means of taped group interviews.

The students for interviewing were selected by the classroom teachers on the basis of having participated in the unit and a willingness to be involved in an evaluation of the snow activities.

The students were informed that the snow unit they had just completed had been recently designed at the University of Alberta and that they were among a limited number of classes who had done or would be doing these activities. They were told an evaluation of the unit was desired and it was felt that those involved could provide very important feedback as to its worth. As participants, their honest opinions were desired, both positive and negative. These comments would have a direct influence on the further development of this unit of laboratory work. The interview transcription, interpretation and validation techniques were explained and participant anonymity guaranteed. This latter point was received with some obvious relief by the students.

A similar procedure was followed with the teachers except that they were aware the design of the unit was the researcher's. Because of the sequence of classes doing the unit, each teacher was interviewed individually. The researcher's familiarity with both teachers reduced tension during the interviews, scheduled for the completion of the unit.

Interpretation Protocol

An individual transcript was prepared for each person interviewed. Rather than a word-for-word transcript, the individual's comments were gathered in a series of short paragraphs based on the interview question(s) asked. Condensation of their remarks eliminated unnecessary phrases such as "eh" and "ah", pauses and other extraneous utterances. When one student verbally agreed with the comments of another the phrase "agreed with..." was inserted. Where possible exact phrases or sentences used by both students and teachers were left intact, including grammatical errors, in order to preserve the "flavour" of the conversation. Following each set of comments the researcher interpreted them in terms of specific values to the student. These were prefixed with an asterisk in order to separate them from the students'/teachers' personal comments.

An excerpt from a fully transcribed interview appears as Appendix E. Examples of the researcher's interpretations of student meanings are found in Appendix F.

The interview descriptions and the interpretations of these descriptions were presented to the students and teachers involved within six weeks of the final interview. This was a longer delay than anticipated but was necessary due to three factors. The schedule of events had been displaced with the switch of Jones' class from a December start to January, as well as school closures due to the weather. This meant that interviews, transcriptions and verifications for the first group now superimposed upon the introduction of the unit into the remaining two classes. The researcher had only evenings and weekends to transcribe and interpret the interviews and during this time had naturally to attend to certain family commitments. The sum total of the interviews, including the special series with the four students in Beta School resulted in the production of thirty transcripts. Together they produced over five-hundred pages of transcript and interpretations. The time involved in the preparation of this mass of data exceeded 200 hours. The logistic nightmare described by Rothe (1979) had been recreated. Nevertheless, the in-school situation was a real situation, one which the classroom teacher must live with on a day-to-day basis. Therefore, delays in implementing the first unit may well have resulted in a more reliable test of the worth of the snow unit itself.

Following the trascription and interpretation of student and teacher statements, arrangements were made to meet with them as individuals or in small or larger groups to describe the methods of transcribing and interpretation, to allow them to view and discuss these descriptions and to give them the opportunity to revise an interpretation where necessary. There were no problems in arranging times for members of my own class. In the case of Alpha School, the principal arranged for the use of the small conference room and the release of the students from class when necessary.

The verification sessions took approximately one half hour each and, following any revisions, ended with a reiteration on the use of the material. Many of the students indicated that they would like to be informed of the eventual results of the evaluation and this was agreed to. Few changes were made. The students, even with a six week delay in some cases, stated that they remembered what they stated and the descriptions were quite accurate. A number of chuckles arose when reading some of the interpretations. When asked to explain, they mentioned that they had been unable to find the precise words for an explanation and that the interpretation had been quite accurate. Typical of the changes made was the interpretation of student W's remark concerning the value of laboratory activities in science courses:

W	Chemistry labs were fun because you can watch things explode and everything.

I assumed that W was being facetious. Nevertheless I interpreted his comments as follows:

- * Chemistry labs were more of a game than a learning experience.

W was quite upset that I had taken his comment literally and stated that the labs were definitely a learning experience, not a game and was pleased to see I was prepared to modify my interpretations accordingly.

The interpretive descriptions were thus verified by the participants and can be considered as descriptions of the meanings the teachers and students have of the snow ecology unit and of the laboratory experience in general terms.

Entry to Class 1, Alpha High School

The class of Mrs. Jones was to begin the unit during the week of December 1, and no later than December 7, 1981 which would allow completion of the two week unit before the Christmas break. Weather conditions forced postponment. December set records for warm weather and no snow was present on the ground. Mrs. Jones was quite agreeable to changing the date of instruction to the week of January 3, 1982 even though it would interfere with planned work in genetics and possibly limit review time prior to the final exam period which was to commence on January 26, 1982.

During the final days of the Christmas holiday the temperature dropped into the -30° range and by January 4th, the first day back to school, there was a snow cover of about 5 cm.

Although the snow depth was less than ideal for optimal data collection by the students, Mrs. Jones agreed to proceed with the unit but was forced to cut back on the recommended time allotment by 20%. She also decided to make the unit the basis for the student project section of the Biology 20 program and used the marking-grid and built-in assignments for this purpose. The weather was bitterly cold during the outdoor work (approximately -30°C) and little snow was available until the final outdoor activity when snow accumulation reached about 20 cm. Since there were now time limitations, little discussion of the data was carried on in class and some students were unable to complete all the activites. Now that the unit was going to represent a significant percentage of their final marks, a number of the students used their own time before class to complete the initial outdoor work for their last data-collecting investigation, then completed it during regular class time.

The weather conditions had been less than ideal, to say the least. As a result the school system had been closed for two of the last four days due to the intense cold. Even though some of the intent and sequence of the unit had, of necessity, been modified, the researcher felt that sufficient work had been accomplished by both the teacher and students that interviewing should proceed as planned.

The time shift in running the unit now had complicated the interviewing schedule. Since the final exams were to be written only two class periods following the completion of the unit, all interviewing had to be postponed until early in the second semester. Mrs. Jones had selected eight students who had completed all possible aspects of the unit and were willing to participate in the evaluation interview. A meeting was held at noon hour on February 5, 1982 at which seven of the eight students were in attendance. The eighth student had left the school at the end of the first semester. The purpose of the evaluation was explained, the value of their contribution emphasized and their anonymity stressed. All were interested in the evaluation and agreed to a schedule in which they would be interviewed in groups of four and three respectively. The interviews were to be held at noon-hour, on the students' own time, so that they would not have to leave regular classes at this point in the new semester. The noon hour restricted the time for an interview to approximately 45 minutes. Because of illness among the students, the interview groups eventually consisted of three students, one student and three students held on February 8th, February 10th, and February 17th respectively. The interviews were held in the classroom/laboratory of Mrs. Jones, the same room in which the students had taken the Biology 20 course. The surroundings were thus familiar to each student. Except for the one-to-one interview, the interviewer and the respondents sat around a small lab bench. The tape recorder was placed to one side of the table for minimum visibility. My familiarity with the school, the room and some of the students allowed for some preliminary conversation prior to the actual interview. Again, the purpose of the evaluation, the presence of the recorder and the anonymity of the respondents was stressed. Except for extraneous noises from the corridors and intermittent public-address system announcements the interviews proceeded without incident and within the time available. The students indicated that they looked forward to seeing the transcripts of the interview and hoped their contributions had been of value.

The teacher considered that the class had been one of her more academic groups. Of the seven students inteviewed, except in one instance, final marks in the course were 80% or over. There is little doubt that the group represented a better than average achievment in the student population.

Mrs. Jones was interviewed on January 28, 1982. The session was held after school in the teacher's classroom. Two or three interruptions occurred but did not affect the continuity of the discussion. During one pause due to a laboratory technician moving some equipment in the room, Mrs. Jones remembered some comments which had not been brought up. These were then incorporated into the interview at a later point. It appears that a break in an interview may be an effective technique as it allows for reflection at a less stressful moment. Having just completed the unit, Mrs. Jones easily remembered many small points that, over a longer interval between event and interview, may have been forgotten.

Entry to Class 2, Alpha High School

The class taught by Mr. Smith began the unit as planned on February 23, 1982 and ran it for the required two consecutive weeks. The classes were of eighty minutes duration and were held every second day. Preliminary information was given and the first booklet handed out during the last few minutes of the class prior to the first day of the unit so that the students would come to class prepared to proceed with the first activity. The weather was snowy and the daytime temperatures well below normal for that time of the year. The snow cover, already sufficient for the studies, increased during the two weeks from about 30 cm to 50 cm depth. The daytime temperature, except for the final outdoor activity, was approximately -25°C. On the final day the temperature reached -12°C. Steady breezes resulted in a severe wind chill. The general conditions were actually ideal for obtaining clear data but definitely uncomfortable for the students.

The teacher reported that all the activities had been completed over the allotted two weeks with little difficulty although final assignments were still being submitted to him during the following week. As a result he requested a short delay prior to any interviewing.

Four students were selected by the teacher to participate in the interview session. Unlike the Jones' class situation, arrangements could be made to conduct them during the school day at a time when I was scheduled for a spare period. The principal arranged to have the students released from class during their final period of the day but requested that the time be limited to a fifty minute block. He also was able to reserve a small conference room for my use.

The interviews were held on March 23, 1982. The intention of the study and my position with respect to it was explained to the students. The use of the recorder was explained, anonymity guaranteed and the value of their contribution stressed. They were pleased that they were to be given a chance to validate their comments and my interpretations of them. We sat around a table and the recorder was placed to one side. The group appeared relaxed and eager to begin. The interview took longer than the allotted fifty minutes and the students were agreeable to extend the conversation for an extra few minutes even though it meant remaining after school. Unfortunately, when the tapes were played later for transcribing only the introductory comments, about one minute in length, had been recorded.

Again I approached the school in order to re-interview the students. The principal, teacher and students were more than willing to do it once again. One student, however, was out of the country and had to be omitted from the study. The second interview was held on April 7, 1982, the Easter vacation having occurred in the interval. The interview ran smoothly and the students seemed to respond to the questions in a vein similar to the first session's. Since the intent of the interview was not the recall of specific detail but impressions and meaning of the unit, the delay did not appear to be a problem.

The interview with teacher Smith was delayed because a time convenient to both Smith and myself was difficult to arrange. It was finally held in May, some eight weeks after the event had taken place. Smith was cooperative in all respects although some details of the unit appeared to have been forgotten. Questions were often modified to dig out the forgotten material and to obtain more generalized comments on both the unit and other laboratory exercises.

Entry to Class 3, Beta High School

Prior to commencing the unit I had noticed that the time table of four of the students indicated spare periods which coincided with my free time. This suggested the possibility of a series of ongoing interviews which could occur after each outdoor activity, as well as after the completion of the unit. All were members of different lab groups. These students were approached and the evaluation set-up was explained to them in the usual manner. All four, two girls and two boys, were quite willing to participate. By matching their spares with my free time two groups of two students each were scheduled. Because of a timetable switch by one student, the second group was unable to have their first interview session until after the second outside activity. Interviews were held in their biology classroom, vacant at that time.

I had initially expected to go with a single group of four or five students for interviewing following the unit, as arranged in the other test classes. This concept was maintained. Four more students, two boys and two girls, representing other lab groups where possible, were asked to participate. They readily agreed. The group interview was held in a small conference room on March 25, 1982. The standard explanations were given to them and the interviews proceeded without interruption. All interviewed students were anxious to see the transcripts and my first interpretations.

CHAPTER 6

INTERVIEW DESCRIPTIONS AND INTERPRETATIONS

Introduction

The meanings given to laboratory experiences by both students and teachers is the main concern of this study. The vehicle used to initiate reflection on the worth of these activities was the researcher-designed winter ecology unit. Through the series of interviews with the students and teachers involved, the overall impact of the snow unit plus various aspects of laboratory work in general were examined and discussed. In order to facilitate interview interpretations the sequence in which the classes attempted the snow ecology unit suggested a division along class lines. The data from the three participating classes therefore appears under separate headings. Since teachers and students view the same event from quite different perspectives, their interview interpretations have been kept separate. Rist (1982) suggested that thematic analysis, the clustering and presentation of material by key themes found by examination of the material collected can be an effective method of organizing qualitative data. An examination of the interview interpretations indicated that they could best be analyzed under the following sub-headings: Background in High School Science; Laboratory Organization, Instructions and Procedures;

Activities, Assignments and Laboratory Evaluation; The Laboratory as a Learning Experience. Teacher interviews were similarly organized under the following sub-headings: Attitudes Toward Science Teaching; Laboratory Organization, Instruction and Procedures; Activities, Assignments and Laboratory Evaluation; The Laboratory as a Learning Experience. A summary concludes each group of interpretations. Since my own class had participated in the snow activities a section devoted to my personal observations and feelings replaced the teacher interview of that specific section.

Throughout the discussion the meanings of both student and teachers are also interpreted in terms of the four regions of being developed by Rothe (1979) and described earlier in Chapter 3. The classification of key responses into one of these categories is a means of indicating differences in the meanings suggested by the students and teachers.

Responses in the Passive Area of Being indicate that an individual is typically bored with a situation and fails to recognize that he is the creator of his own values. The need for external expectations is also characteristic of this area. Responses indicating the Immediate Area of Being suggest that the laboratory is of value only because it eliminates boredom by being a new instant of pleasure. In the Responsible Area of Being, closer to the center of the inner being of a person, the respondent would indicate that a personal decision is part of the experience and that others are affected by his/her choice. A person who bases choice on intuitive and spiritual grounds, and prizes qualities such as social justice and harmony with his fellow man, is responding in the Transcendent Area of Being. This analysis of values is thus itself of value to the evaluator as part of a decision-making process.

To preserve the anonymity of the participants, each student has been assigned a letter code (B, C, D) while teachers have been given fictitious names.

The classes participating have been designated as Class 1, Class 2 and Class 3. Class 1 includes the students and teacher at Alpha High School who completed the snow ecology unit during January, 1982. Class 2 consists of the students and teacher at Alpha High School who completed the unit during February, 1982. Class 3 involves the researcher's students who completed the unit during February and March, 1982.

When quotations are used, they are in the abbreviated form described in Chapter 5.

Descriptions of Student Meanings, Class 1

Background in High School Science

Seven students, designated B, C, D, E, F, G and W, were interviewed. In order to get the students talking and to develop a relaxed atmosphere, they were simply asked to name any science courses they had taken in senior high school. All the students had completed Biology 10 and had just completed the Biology 20 program. Students D and F had also taken Physics and D, E, F and G had completed at least Chemistry 10. When asked to describe laboratory work they had performed in their science courses students D, F and G mentioned activities involving the microscope and dissections. They were then asked to describe some of the snow activities in which they had been involved. Specific activities were noted. These included constructing equipment such as the weigh scale pans, building a quin-zhee (snow shelter) and recording temperatures inside and outside of it, examining snow strata, aging snow crystals, and recording snow temperatures, densities and snow depth.

Laboratory Organization, Instructions and Procedures

The students indicated that the materials in the instruction booklets appeared well organized and in a logical sequence. W thought the division of the student materials into two booklets reduced possible confusion. Clear understandable instructions are considered a basic requirement for laboratory activities. This indicates meanings in both the Passive and Immediate Areas of Being. F considered that the assignments were easy to do because of the apparent logical order of steps and clarity of instructions in presenting data and any necessary mathematical calculations. These laboratory characteristics are valued by the student and have meanings in the Immediate Area of Being.

The homemade equipment appeared to function adequately although the lack of snow limited the number of measurements made. A small problem was noted:

> E The only problem encountered with the student-made equipment was with the balance pan. It was so light that the wind caught it and made reading the spring balance a bit of a problem. Using the snow sampler as a balance pan (heavier) might be one way of reducing the problem.

Malfunctioning equipment can lead to some frustration and possible lack of interest in proceeding with an investigation, resulting in meaning for the student in the Passive Area of Being. However, the fact that E was concerned enough to suggest a solution which might benefit others indicates meanings in the Responsible Area of Being.

The students all mentioned the lack of snow as a problem for recording temperatures at the suggested depths, observing strata and having sufficient time for building the quin-zhees. The actual observations made posed no difficulty. However, C was concerned that not all the required measurements could be made and would prefer to follow all the possible steps even though modifications to the lab may be due to a real-life situation. This indicates meanings in the Passive Area of Being.

W noted that the thermometers were not calibrated beyond -10°C and that he estimated lower temperatures by assuming that the calibrations would have remained constant. This indicated a desire on the part of the student to take some initiative in determining a more accurate reading which he could share with his fellow group members, a meaning within the Responsible Area of Being.

The topic of predicting results before collecting the data was raised. Students D, E and G noted that their predictions were similar to the actual temperatures recorded in the snow but that it was warmer than expected. E and G expected warmer temperatures:

> W The set of temperatures beneath the snow were surprising. It was very cold out (about -40°C). It was very warm only about -7°C to -8°C at the bottom of the snow. It was much warmer than expected.

Predicting results appears to increase interest and allows for comparisons. Meanings are in the Immediate Area of Being.

The students were bothered to some degree by the prevailing climatic conditions. W illustrates this concern:

> W One of the main activites was getting cold. It was around -40°C outside and windy. It was warmer on the day the snow shelters were built.

The other students also referred to the cold. They noted that it was a problem mainly on the first day out. This suggests meanings in the Passive Area of Being. Interest appeared to overcome resistance to the weather indicating meaning in the Immediate Area of Being.

The students concurred that the time available for the unit was insufficient due to the delay in commencing the program. If they had followed the expected time line there would have been no problem in completing the unit. Some of the students actually gave up free time in order to complete activities. This is illustrated by C's comments on the quin-zhee construction:

> C Snow shelter construction involved piling up the snow into a 6 foot by 12 foot pile. It was allowed to set over a half hour time priod. A hole was dug into it and the centre was hollowed out so you could sit in it. The shelter was worked on before class in order to complete the piling stage before doing the investigations which were done in class time.

C exhibits sufficient interest in the activity to give up personal time to assure completion of the exercise. This suggests meanings in the Immediate Area of Being. However, the teacher had indicated that a high mark value was attached to the completion of the unit. Since the students had indicated a desire to attain high grades, the grades rather than interest in the activity may have been the motivating force. The meaning in this case could be in the Passive Area of Being.

Activities, Assignments and Laboratory Evaluation

The students were questioned about the laboratory reports required and the evaluation of their work. W indicated no problems with completing the assigned work and noted that the reports were evaluated fairly and nice high marks were obtained. He appears to associate a fair evaluation of laboratory work with high marks. This suggests meanings in the Passive Area of Being. This feeling was also expressed by B, C, E, F, and G.

D thought that the mark assigned might be based more on the answers to questions than the effort put into the work. He appears to see more in a laboratory exercise than the physical "fun" of doing it and that analysis of data leads to more learning. This indicates meanings in the Immediate Area of Being.

G thought the difficulty level of the questions in the discussion section of the report was reasonable and could even have been harder:

G The answers to many of the discussion questions were right there (in the data) and one really didn't have to think.

G also stated that data which can be easily examined and analyzed is important to laboratory work. Graphing posed no problem and density calculation appeared easier since density calculations had been done in population studies earlier in the course. Satisfaction with the collection, presentation and discussions of data has meaning for the student in the Passive Area of Being.

A question was asked about the "fill in the blank" exercise following the two research articles. C thought the articles probably would not have been read or would simply have been skimmed without the required assignment. Students W, B, E, F and G agreed. This suggests meaning in the Passive Area of Being. D thought the assignment was a good test to see if this information was understood and remembered. He would have read them anyway because they were of interest. This indicates meanings in the Immediate Area of Being. F thought that the two articles would have been best read at the beginning of the unit. Then information concerning animals under the snow, for example, could have been supported by the first set of activities (measuring temperatures under the snow). The student appeared to prefer knowing the answers in advance rather than examining raw data and drawing conclusions from it. G agreed. This suggests meanings in the Passive Area of Being.

Students W, B, and C indicated the necessity of requiring a laboratory report at the end of an investigation:

> B A lab report turned in at the end of an activity is probably better than no required assignment. You put a bit more effort into the work; do a better job.

B is not willing to put out maximum effort unless there are demanded requirements, indicating meanings in the Immediate Area of Being. W and C agreed with B. E prefers a more challenging analysis of laboratory data and the elimination of simple right or wrong answers. A suggestion was made that a summary paragraph or its equivalent be added to each lab exercise to tie everything together and allow for personal interpretation of the data. This suggests meanings in the Responsible Area of Being, a desire to make personal decisions not restricted by given limits.

The Laboratory as a Learning Experience

In order to probe more deeply into their feelings about the laboratory experience, the students were asked to indicate their preferred activity in this unit. Except for student E they all indicated that the building of the quin-zhee had been a highlight which led to an indepth discussion of this activity. B indicated that the physical building of the shelter was of more importance than the data recorded about its properties. This suggests meanings to the activity in the Passive Area of Being. The others saw the activity as having value in a possible life-and-death situation if stranded in adverse winter conditions, besides being fun to construct. D saw usefulness in the information gained on the effects of the quin-zhee on temperatures. He noted that as a back packer in winter he had already been familiar with snow shelters and had slept in a quin-zhee on occasion. Although he knew it was warmer inside one than out in the air, he now was able to understand why and saw the shelter as useable in a number of situations. He was surprised at the actual warmth in the shelter. This suggests meaning in the Responsible Area of Being. The student is acting on his own volition and sees the information gained as having value to others. G had further consderations. She stated that she had gone home and taught her little sisters how to build a quin-zhee.

> G Little kids always like to build snow forts. If children were taught how to build a proper quin-zhee they might use it sometime. We ourselves could use it sometime. My sisters are seven years old. They liked building the shelter, had fun and hollowed it out themselves and had a great time doing it. It was all fun for them but they could use this knowledge some day in the future.

G has extended her thinking beyond the self. She takes responsibility for the actions of others. Her meanings are in the Responsible Area of Being.

Some students suggested additional activities to the snow shelter exercise. W thought that it would be interesting to build a shelter in a remote area and sleep in it. If a ledge was built to raise one from the floor it would raise him above the cooler air at the floor. W had obviously grasped the basic principle of snow insulation. He gave them meanings in the Immediate Area of Being and C thought a candle would raise the temperature inside even higher. She also recommended venting to prevent carbon monoxide poisoning. This suggests meaning in the Responsible Area of Being.

The students were asked to consider themselves as advising a friend who might select a snow unit as an option, on the value, if any, of taking the unit. Students W, D, E, F, and G noted that they would probably recommend the unit. E thought there were other options just as valuable to people, indicating his meanings were in the Responsible Area of Being.

A question was then posed which suggested that this type of laboratory work could be done in the classroom without the necessity of activities. The responses revealed much about student interpretations of the laboratory experience. W thought that it was possible to study the unit from theory only but the activities broke regular classroom routines. This suggests meanings in the Passive Area of Being. The act of participating was thought to make learning easier, certainly easier than merely reading. This suggests some meaning in the Immediate Area of Being. B was in agreement with W. He added that the handling of equipment and other techniques were requirements for university work. C thought that one thinks of a laboratory situation more often and thus remembers the material learned a bit better. She also noted that laboratories do have to make sense, otherwise book work is easier. Laboratories with practical application outside the school environment were also seen as having more value. This indicates meanings in the Immediate Area of Being.

Laboratory experiences other than the snow units were also mentioned. Students E, F and G commented on chemistry laboratory activities. They were considered easy and fun. G stressed that observing a real reaction was a vital part of the laboratory experience. When asked what chemistry would be like without laboratory work, E, F, and G all stated that the laboratory was necessary for first hand observations. This suggests meanings in the Immediate Area of Being. E added that a laboratory which simply involves something already understood is of little value. Meanings of laboratory experiences in this case are in the Passive Area of Being as the student does not see the laboratory as simply reinforcing knowledge and not approaching the topic in a new way.

In biology, G indicated a dislike of dissections:

> G I did not like any of the dissections and was bothered by the fact that the organisms dissected were once alive. The dissections were gross. The anatomy learned however was considered of some value; the physical dissection was the problem.

G performed the dissections but only out of necessity. This suggests meanings in the Passive Area of Being. Something of value was noted, and thus has meanings in the Immediate Area of Being. Genuine concern for the fate of organisms that are dissected may indicate feelings in the Responsible Area of Being. F concurred with G. E stated that there was value in knowing where the major organs and systems of the body were located suggesting meanings in the

Immediate Area of Being.

D states that learning by experience is best. Laboratory work is tougher in general than text book learning but is more interesting and involves practical experience. Facts are no longer just facts. The value of the quin-zhee for example was not only that it illustrated how organisms can survive the cold by living under the snow in the winter time, but in its practical use as well. This suggests meanings both in the Immediate and Responsible Areas of Being.

E indicated that although he had learned something about the insulating properties of snow, the relief from the day to day classroom routines seemed the most important aspect of the snow ecology unit. This suggests meaning in the Passive Area of Being.

F considered the experience worthwhile even if the physical conditions outdoors were rather extreme. Experiencing the laboratory activities was essential and preferable to book learning. A key factor in laboratory work was doing something with a possible future use. The Immediate Area of Being is indicated. G considers classroom routine work as boring, (Passive Area of Being) while the laboratory is a release from the boredom and renews interest (Immediate Area of Being). She also notes that activities which apply to real life situations are of greatest interest.

The students, in general, expressed satisfaction with the unit and felt it had been an interesting experience.

Description of Teacher Meanings, Class 1

Attitudes Toward Science Teaching

Jones was asked why she chose to teach biological science. She stated that it was a personal interest. She had taken Biology as a major at University along with a minor in Chemistry. As a result it was comfortable to teach in these areas. Earth science taught at the junior high level would also be enjoyable. Jones considers that a good background in a teaching subject area is required and that teaching in an area of interest and competence is more enjoyable and rewarding. In terms of personal satisfaction she has meanings in the Immediate Area of Being, but in terms of classroom competence the meanings are in the Responsible Area of Being.

Jones was asked to comment on the high school biology and chemistry programs in an attempt to obtain her personal feelings on the sciences. She had taught Biology 10 and 20 plus all of the chemistry courses. She felt strongly that, particularly in Biology 20, an emphasis should be placed on local organisms and environment which students can see as more meaningful both in the classroom and the laboratory. Laboratory activities can demonstrate local area biology better than classroom instruction. These are meanings in the Responsible Area of Being as they indicate concern for the student, even though the student meanings could be in the Immediate Area of Being.

When questioned on how she handled lab (field work) Jones indicated that lab work in biology takes more preparation than an equivalent chemistry lab. Supervision of potentially dangerous situations is a requirement of a lab instructor. Jones considers the lab of sufficient value that she is prepared to do extra work and supervise high risk situations to allow the students to participate in lab activities. Personal involvement with students during an activity insures that everyone is doing fine and allows for discussion of any question raised. These are meanings in the Responsible Area of Being.

The chemistry course was described as a package of workbook-type classroom and laboratory exercises. The packages appear to have limitations. Additional labs have been developed, along with extra class handouts. This is necessary because the students tend to see the course as a package and limit themselves to the package. The extra effort on the part of the teacher to attempt to expand the interests of the students indicates meanings in the Responsible Area of Being.

The interviewer asked Jones how she felt about teaching. Her feelings were highly positive and felt that a person who does not find teaching an exciting and rewarding experience probably does not feel good about teaching. Positive reactions from both students and colleagues are definite rewards although correcting tests and assignments is not an enjoyable experience. This suggests meanings in the Immediate Area of Being.

Maintaining student interest (motivation) was then discussed:

Jones Probably more time should be spent in this area. It is a personal teaching weakness. The attitude is taken that the students are in Biology because they want the course and are here to learn about it, so let's get at it. The same with chemistry. I don't try to do a "sell job". You may not like it or love it but in order to get on, let's get down and learn it. Motivation could be a major area of self-improvement.

Jones continued by describing some techniques she used to keep up student interest. They include problem solving, illustrating things on the blackboard, discovery work where possible and as much as possible. Variety is the key; labs, films, discussions. Note taking is also involved. Variety is valued as an instructional strategy in order to maintain student interest. This suggests meanings in the Immediate Area of Being. The teacher's recognition of potential weakness in her motivational techniques suggests meaning in the Responsible Area of Being.

Jones was then asked to describe her expectations concerning student behaviour in the science classroom:

Jones Ground rules are set out at the beginning of each semester; the rules of the game. Students are expected to follow the rules and present work at an expected level. Expectations are discussed; attitude, attendance, behaviour and quality of work. Early

> tests, exams and labs are learning exercises for subject material and teacher quality of work demands. This sets acceptable behaviours and everything rolls on from there.

Setting ground rules early into a semester is valued by the teacher and, in the opinion of Jones, the students as well. Meanings are in both the Passive and Immediate Area of Being.

Laboratory Organization, Instructions and Procedures

A description of student activities was requested. Jones noted that the first two activities could probably have been completed in one day. Problems had occurred with students remembering instructions. If the data sheets had included an outline of the precise measuring steps there would have been less referring back to their instruction booklets. This had been feedback from the whole class. The teacher is prepared to listen to constructive comments from her students and act upon them where possible. This indicates meaning in the Responsible Area of Being. She also values the traditional "scientific method" approach, with its well organized and clear lab procedures, ease of data recording and efficient use of time, meanings in the Immediate Area of Being.

The teacher had permitted the students to organize the lab work distribution on their own. She had however arranged groups of four students. They seemed unable to successfully allot work on their own and for the first two outdoor activities there were too many students in a group for the number of activities to be done:

> Jones Some would watch while one did the work or one would read out the instructions while another recorded data and tried to keep warm, one did nothing and one does the activity. If two had been working at the same time on Station A and at Station B, all would have been working at the same time.

Jones expects the students to take responsibilities for their activities, a meaning in the Responsible Area of Being. Labs are valuable as long as the students experience and work at an activity. She views student participation as to the students' advantage and is thus in the Responsible Area of Being. However work for the sake of being busy suggests meanings in the Immediate Area of Being.

The teacher was asked about the time required to complete the unit, which had been reduced for the reasons described in Chapter 5:

> Jones An extra period could have been used but activity one still probably could have been done in a single period. If the procedures had not been a problem this would have been possible. Rereading, warming up, etc. took up time. A full period for pooling data and doing the reading assignment would have been helpful. The students had to throw up their data on the board and then class results were calculated. Time was needed for the unit.

Time is noted as a requirement for obtaining maximum value from a lab. A lab, if pushed, results in disorganization and reduces the learning experience. The pooling of class data allows for class discussion and sharing of ideas but requires time. These are meanings in the Responsible Area of Being.

Jones was asked to give her general opinion of the unit:

> Jones It was good and I liked what it was trying to achieve. What it set out to do it did well. For a Biology 20 level course it was extremely straight forward and possibly could have been more demanding, taxing their intellect a bit more. For example, questions on ski-doo regulations; organisms affected by ski-doos; go out and observe animals actually living in a subnivean environment, something that goes beyond the activities.

The initial meanings given to the unit by the teacher are in the Immediate Area of Being. The concern shown for more challenging material including man and other organisms in the environment expresses meanings in the Responsible Area of Being. The activites were also described as being fun, teacher preparation time minimal, and equipment simple to build and put together. This suggests meanings in the Immediate Area of Being.

Jones noted that the unit took some organization but not an excessive amount. It ran fairly smoothly and she was pleased with it. Jones suggests meanings in the Immediate Area of Being. She values labs which she personally finds interesting. In recognizing the effect of time restrictions in the unit she was prepared to accept late assignments if submitted within reasonable limits, suggesting meanings in the Responsible Area of Being.

The teacher was asked to describe the conditions under which the outdoor activities had been run. The intense cold and lack of snow were mentioned as definite problems. Some students were not prepared for outdoor work although pre-warned. However, the students seemed to enjoy their work. The teacher indicated that the apparent enjoyment of an activity by students is a measure of interest level and the success of a lab activity, particularly if under adverse environmental conditions. This suggests meaning for both students and the teacher in the Immediate Area of Being.

Jones was questioned on her familiarily with snow ecology. She indicated that it was new material and actually not read over in advance. She was as amazed as the students with the effectiveness and ease of building the snow shelter and the good results obtained. She mentioned further student reactions:

Jones	Some students suggested using a candle in the quin-zhee and wanted to try it out. One mentioned that his/her father said that a candle should be kept in the car in winter. This could lead to an extra activity.

The teacher was asked if she thought that the objectives of the unit were achieved. Her response was in the affirmative. However she had problems with the suggested marking grid:

Jones	Marks were extremely high. The acitivites led the students to conclusions so nicely that answering the questions became very easy. The results of the activities were so good. This could be both a positive and negative aspect of the unit.

The teacher desired a better distribution of marks, which seemed to her to be generally too high. She notes that a successful lab must achieve its pre-determined objectives and produce data leading to clear conclusions and relationships. These are meanings in the Immediate Area of Being. Labs must also demand extended thinking and the application of the information learned suggesting meaning in the Responsible Area of Being. She has mixed feelings about high marks, preferring evaluations which discriminate between student achievement rather than having a criteria referenced base. This suggests meaning in the Immediate Area of Being.

Activities, Assignments and Laboratory Evaluation

The teacher was asked to comment on the evaluation guidelines. Jones stated that the suggested marking grid was so straightforward that it was difficult to take off marks. She preferred a grid that emphasized interpretation and conclusions, which would then provide a spectrum of marks instead of a general high success rate. The teacher in her own lab evaluation has students write out a lab procedure, collect and record data and answer questions drawing them to conclusions. Marks are assigned to the questions, not the actual results obtained. The synthesis of the data is the most important part.

The teacher does not see the procedures used by the students, effort, or data collection itself, of great value in the evaluation of lab work. This suggests meanings in the Passive Area of Being.

The teacher sees a value in a "participation" mark only when the students perform a lab with above average effort and initiative, not just for the sake of activity and/or marks. The apparent effort may thus be due to the mark value and not the personal gain from it. Her view of participation marking is in the Responsible Area of Being whereas she sees the students often in the Passive Area of Being. There appears to be some value in marks as a motivating force, implying meanings in the Immediate Area of Being.

Jones had used the snow unit as the basis for the project section of the Biology course. It had not been designed for this purpose. She was asked how it would have been marked if it had been simply a lab unit. Jones replied that the marks for participation might have been lower:

> Jones The mark value of the unit was high enough to have the students really out giving their darndest. Everyone was trying to impress me somehow because of the assigned "participation" mark and I was watching... They worked above and beyond, helping others, and had their quin-zhee built at the start of the class.

The teacher added a few more general comments. She enjoyed doing the activities. Setting up the unit into parts 1 and 2 was effective. Because of the reduced time available the students were asked to proceed at their own speed but as quickly as possible. As a result, at one time half the class was outside while others were still working in class, because part one had to be completed before part two was given out. These time limitations caused problems in the submission of lab reports. Marks were deducted if they came in too late, in order to put pressure on the students. This suggests meaning in the Passive Area of Being for the teacher. If students viewed the penalty clause as the only reason for submitting a report, their meanings are also in the Passive Area of Being.

The Laboratory as a Learning Experience

A question was asked to obtain the teacher's opinion of laboratory work in the biological sciences:

Jones They are necessary. It is "doing science". Not doing labs would be a step backwards. There is a stress on content at the senior high school level but more lab/activity work, such as pond studies and snow ecology, is preferred to memorizing things about biomes. A pond study in the fall; snow ecology in winter. Tests on materials are necessary and content has to fit in the time available. Lab activities should be a compulsory part of the course.

Jones describes the lab as a highly valued part of a biology course. Its hands-on activities are considered a highly significant part of learning science, important enought to be compulsory. The student is viewed as benefiting from the lab experience in a way simple content cannot equal. This suggests meanings in the Responsible Area of Being. Tests and content appear to reflect meanings in the Immediate Area of Being.

I suggested to Jones that everything taught in a lab could be taught in a classroom setting and probably with more efficiency:

Jones	No way. It was worthwhile for the students to go through the discovery process. For example, the artificial pond study done last year. There was great excitement in the class when they discovered Daphnia giving birth, its pouches bursting. It was exciting to all of us. They were all interested, saying "look at this. Isn't it neat? What's this?" Even identifying species, so call "boring" guide on who's who, was thought to be just thrilling. It was a lot of fun. I would hate to have to draw or throw up a transparency and say that it was Daphnia, a water flea. For them to discover themselves was much better. I do not agree with the idea.

Her use of the term "discovery" is in terms of a guided learning experience. She observes that when "boring" work becomes exciting to students, the value of the laboratory activity is more than justified. The hands-on experience simply cannot be duplicated in the classroom. The teacher views the lab as an educational experience which has significant value to all concerned. This suggests meanings in the Responsible Area of Being.

Jones identified a general problem encountered in the classroom which also had implications in laboratory work; a lack of student desire to read. They would sooner ask than sit down and read instructions. They know teachers will provide the answers:

> Jones I personally try to work on this. I allow only so many questions per person in a lab situation. "Don't ask me! That is the easy way out. Read it". In their answer to questions I am appalled at their comprehension. They talk about things not asked. As a science department or teacher, an objective is to help them in this area.

Jones' description of student reading interest indicates that they have meanings in the Passive Area of Being. Her concern for the students and attempts to improve their reading habits indicates meanings in the Responsible Area of Being.

She extended this concern to aspects of the snow ecology unit, specifically the "fill in the blank" assignment. Additional questions which required the student to write or formulate sections and reword ideas, rather than just use words, seemed necessary:

> Jones They may not have got as much out of the article as it appeared. More work on their part was needed. Possibly four questions which require five to six sentence answers would help build up their writing skills and comprehension level. It also resulted in a better mark distribution because lazy students won't do it; they can fill in the blanks though.

Her comments again reflect concern with reading ability and she suggests positive changes in the snow unit which would help with student comprehension and writing skills. This suggests meanings in the Responsible Area of Being. She notes that lazy students like the minimum of work but says nothing about the slow learners in a class. This indicates meanings in the Immediate Area of Being. She continued along similar lines:

> Jones The student preferred doing the snow unit to a regular research paper. At 20% of the final course mark it appeared to be an easier way of getting grades.

The teacher indicates that when students are given the choice they will take the easiest route to obtain good grades at the expense of more challenging and rewarding work. This suggests that she assumes the students have meaning in the Passive Area of Being.

From a personal point of view the teacher noted that the snow unit did not require any special background knowledge of winter ecology. The teacher thus felt secure in presenting the unit to the class, a factor considered to be of value when determining whether to attempt an investigation. Other characteristics of value include labs which motivate students to think about additional self designed activites, and labs which impress the instructor, thus raising teacher enthusiasm which in turn has a positive effect on students' attitudes. These are generally meanings in the Immediate Area of Being. However, when Jones notes that positive teacher attitudes have positive effects on the students, the meaning is in the Responsible Area of Being.

When asked if she had a reaction to the mandatory inclusion of the unit in Biology 20, Jones' reaction was positive:

Jones I hope to do it again anyway when next teaching Biology 20. It is a problem in the first semester due to lack of snow and low temperatures but in the second semester it is ideal. If there were outdoor problems then library type studies could help back it up. I like the topic. The students were extremely interested in snow ecology. An appendix at the end of the unit including research topics, source books, etc., would be valuable. This would help if a full research paper was to be prepared.

The positive view given to the unit as the result of personal interest in the topic and observed student enthusiasm and attitude toward the unit are meanings in the Immediate Area of Being. When the teacher suggests improvements which would be beneficial to the students the meanings are in the Responsible Area of Being.

The teacher was asked if there appeared to be any application of material learned to everyday life of the student:

Jones Time was needed to draw loose ends together. The students were surprised at the ease of making a quin-zhee and its warmth. At least one student mentioned its value if stranded in a

> car or skiing. The students appeared to come away with the idea of snow as an insulator. Although the students appeared to suggest a warming trend under the snow, their predictions were far off the actual results. The actual warmth and high termperature were surprising. Predicting results prior to the activity made them think in advance.

Clear and surprising results make the results of a lab more effective. This indicates meanings in the Immediate Area of Being. Applying the information to potential future use would suggest meanings on the part of the teacher in the Responsible Area of Being, but from the students' point of view, only in the Immediate Area of Being, unless the knowledge was used to help or instruct others. The teacher considers the prediction exercise before the activity as making the data collected a more effective learning experience for the students, indicative of meanings in the Responsible Area of Being.

Jones was asked for any final comments. She considered that a good lab exercise concludes with an open-ended situation which challenges a student to think more about the information learned:

Jones In the quin-zhee lab report there are areas of expansion possible; areas which could challenge the student. For example, would they use a candle in the shelter? What would be the drawbacks? How would they overcome the carbon monoxide build up or, as they say, oxygen depletion? How would they change the design? Could they even draw diagrams of different styles of shelters they would like to try to build? Talk about the pros and cons of

> each design. How could you overcome wind blowing in the door if no cover was available? Just to get them thinking about the things they did.

The teacher views the snow ecology unit as extending the students' learning beyond the immediate laboratory experience. The meaning appears in the Responsible Area of Being.

Summary of Student and Teacher Interpretations, Class 1

Passive Area of Being

A number of students noted their reluctance to participate in animal dissections, suggesting that an apparently distasteful situation can considerably reduce the value of laboratory work. Malfunctioning equipment and the inability of students to complete required data collection, whether due to lab conditions or time, often led to frustration. A few students also noted that they liked labs in which they knew the results in advance and were not required to make conclusions. Physical discomfort, such as the intense cold during the unit, may also have negated the positive aspects of a laboratory experience.

The teacher mentioned a lack of responsibility on the part of the students to properly organize themselves and to share the work load for data collection. Prescribed group sizes seemed necessary.

Some students indicated a reluctance to read instructional materials in depth, which caused procedural difficulties in the field. The teacher noted that many students had to be "forced" to read and that reading was a general problem, not limited to laboratory work. Students noted that a required reading assignment in the snow unit was probably done in depth only because of the mark value assigned to it.

All participants gave indications that marks might, in some cases, be the prime reason for completing work. Some students also suggested that a teacher marked fairly if the mark was quite high, also implying the converse.

Immediate Area of Being

The participants recognized a number of factors which they considered characteristics of a good lab experience which had been exhibited in the snow unit. Procedural information must be well organized, appear to follow a logical sequence and provide clear instructions. Reading the materials is usually no problem but is enhanced if the topic has a high interest level. The students also mentioned that interest in their work generally overcame the particularly poor conditions (weather) which were experienced during the snow activities. Interest was also increased by teacher enthusiasm for an activity and by requiring students to predict results in advance.

A laboratory should be organized in such a manner as to keep teacher preparation to a minimum and not require the teacher to have an extensive background in the lab topic.

A laboratory report, plus its evaluation, is expected following an activity and is seen as providing extra incentive for doing the exercise well. The students and teacher consider that analysis of data and the drawing of conclusions is of major importance and that any assigned marks should be weighed in favour of this area. The students do wish to obtain clear, distinct data which can be succssfully analyzed. The teacher also mentions that questions which demand more extensive analysis are required in order to obtain a wider range of marks, which was one desired effect.

The lab experience is also seen to be fun, personally enjoyable and a break from regular classroom routines.

Responsible Area of Being

The teacher considered laboratory work to be an integral part of any science programs. It is "doing" science. The work and learning cannot be dupliated by regular classroom instruction. Students need to see things for themselves in a hands on situation. The results are increased interest, enthusiasm and a desire to learn. The teacher sees the use of local organisms and the environment as providing students with a more meaningful experience.

Student viewpoints mirror the teacher's impressions. First hand observation, not reliance on the written or spoken word, is essential. Facts are no longer just "facts". Personal decisions are involved. They consider that participation appears to make learning concepts easier, improves long term recall and their interest in the subject matter is greater. The lab is a more effective learning experience than classwork alone and if there are any practical applications of the activities beyond the classroom, all the better.

All participants noted the importance of sufficient time as an overall factor in laboratory work, probably emphasized by the lack of it during the unit. Students were concerned with accuracy in procedures and data collection. The teacher noted that time was required if meaningful discussion and comparison of data was to be done when pooling each group's information.

The teacher noted that laboratory work often involves a high risk situation and requires careful supervision on the ongoing activities. Nevertheless the positive effects of the laboratory experience on all the participants are such that they overweigh the negative aspects. Where activities are weak or non-existant, the teacher is prepared to supplement, modify or develop investigations.

The teacher thought that lab reports are effective in making the students analyze their work and develop definite conclusions. Marks should be assigned accordingly. Some students suggested that they desired questions which required higher level interpretation of the data. The students felt however that some consideration, reflected in the grading of a report, be given to unusual or extra effort when noted by the teacher.

Following the unit the students and teacher were sufficiently motivated to suggest changes and additional activities. They considered the open-endedness of an investigation as being of high value.

The highlight of the unit was the construction of the quin-zhee. It appeared to exemplify those aspects of the laboratory experience valued by the participants. Most saw the activities as also providing them with something of use outside the school setting. As a result two students duplicated the quin-zhee activity to show others the potential value of the knowledge gained.

Descriptions of Student Meanings, Class 2

Background in High School Science

Three students, designated H, J and K, volunteered to participate in the interview session. The opening question asked the students to describe previous experience in high school science. Two indicated that they had completed both Biology 10 and Chemistry 10, the other had taken Biology 10 only. They were all familiar with laboratory activities and they mentioned biological dissections and microscope work as well remembered experiences. The interviewer now turned to the snow ecology unit. The students noted that a number of activities had taken place including the measurement of snow densities, examination of snow strata, recording of temperatures and construction of the snow shelter or quin-zhee.

Laboratory Organization, Instructions and Procedures

The organization of the student booklets was discussed. H and J thought the material was organized in a logical sequence and the reading level not difficult. H mentioned that the materials in Book 2 were more difficult than in Book 1. More difficult work should be explained in class and covered step by step. This would clarify the little things you need in order to proceed. H suggested that there would be more benefit from the activities if the teacher would give an overview of the entire unit. These are meanings in the Immediate Area of Being. J stated dissatisfaction with the Inuit terms (scientific language) used in the booklets and indicated a preference for a minimum of new terms. J also thought the teacher should go over the materials in class and tell the students what to do in a step-by-step manner. This indicates attitude in the Passive Area of Being, since the student is not prepared to accept the responsibility for becoming familiar with the activities on her own initiative. K also reflected similar opinions.

One of the class activities involved the manufacturing by the students of some measuring devices from local materials. The snow sampler did pose something of a problem:

> J There were problems with the snow sampler. They were too flimsy. Proper equipment should be provided by the teacher. Using poor equipment for lab work is not desirable.

J indicates little personal satisfaction from using self-made equipment. Sturdier and more accurate teacher supplied equipment was desired. The student considers accuracy of measurement in a lab to be a valuable feature. Although the idea of using student made equipment appears to be in the Passive Area of Being, the concern for accuracy in data recording suggests some meaning in the Responsible Area of Being.

The recording of laboratory data was then discussed. H and J found the prepared data recording forms useful and easy to use. The formal lab report (results/discussion form) ranged from reasonable tasks to more difficult ones. Many of the questions made one "think hard" and beyond the information collected. K considered that this feature was a valuable part of the lab activity, indicating meaning in the Responsible Area of Being. K could see no value in recopying data from the field records to the lab report but liked the idea of questions that made one extend his thinking.

A specific question was directed to problems associated with the graphing of temperatures within the snow. All students indicated few problems with graphing. H and J suggested that graphing techniques learned during a population study unit made the work simpler. Both stated that they valued the use of techniques from one area to another. These are meanings in the Immediate Area of Being. J then mentioned that the population unit they had been studying had been interrupted in order to begin the snow unit. She felt that this disrupted the unit and was not the appropriate thing to do. This idea is in the Immediate Area of Being as it does not indicate a concern for others in the class who may also have been affected, which would have indicated meaning in the Responsible Area of Being.

At this point K interjected that there had been a problem noted when doing the actual temperature recording. The thermometer had to be read the instant it was taken out of the snow to record the snow temperature. Some groups were slow at their reading. Accuracy in recording data is of high value to the student (Immediate Area of Being) and data should provide meaningful information to everyone (Responsible Area of Being).

Predicting results in advance of a data recording activity was a feature of the snow ecology unit. When questioned about it, the students indicated that it made the lab more interesting since it was a check to see what you did or did not know. These meanings are in the Immediate Area of Being. K uncovered a problem:

> K With regard to the prediction required, everyone basically knew it would be warmer under the snow at the bottom layer. It was hard to compare temperatures since the "prediction" air temperature was different from the actual air temperature. The snow was about 42 cm deep and the temperature at the bottom about 0°C to 1°C.

K prefered to predict using the actual ambient temperature as a starting point to enhance the results, meaning in the Responsible Area of Being. The apparent knowledge of the sub-nivean temperatures, however, seems to have reduced the effectiveness of predicting. It had to be done anyway. This indicates meaning in the Passive Area of Being.

The cold weather conditions were stressed by all students. H and J stated that few students were prepared (clothing) for the first outdoor assignment but made quick corrections for the next activity. By the final exercise the weather had warmed up somewhat and was more tolerable. Neither mentioned any problems with the first outdoor activity. Although the harsh weather made the field activities less enjoyable, the lab activities were of sufficient interest for them to want to continue with the unit. These meanings are within the Immediate Area of Being. When one of the students in H's lab group mentioned having to read the instruction book while outside, the students felt it was their own fault for having to do so. This indicates meanings in the Responsible Area of Being.

K was unprepared to perform the first activity. She had read the instructions but was still not sure what to do:

K There was a lot of standing around and reading instead of doing the activities. More teacher discussion on what the activities were all about would have helped. More class time was needed. The class was told only to read to page so and so. The material was given the previous period and everyone was told to read it. Class time should have been given to do the reading.

The student prefers not to attempt unaided investigation because of the extra effort involved. Class time rather than student's time is preferred for assigned work. This indicates meaning in the Passive Area of Being.

The students apparently liked a lab group size of from three to four members. However, K thought that a large group (about 10 students) could build the snow shelter more effectively since it would involve less physical work per person. This indicates meaning in the Passive Area of Being.

Activities, Assignments and Laboratory Evaluation

The discussion turned to the reporting of laboratory work in general and of the snow unit in particular. H indicated the necessity of some type of final report:

H It makes you concentrate on the work a bit more, since it will be marked. Without a report people will just fool around and not pay attention. With an evaluation there is more of an attempt to get something done in the lab... The report makes you learn more because answers have to be written down and thinking is required before you do.

The student would not put out maximum effort unless some reward was forthcoming, particularly marks. This meaning is in the Passive Area of Being. The student takes little or no responsiblity for her actions. However the student does recognize that there is value to writing a report because learning appears to occur by doing so. This is in the Immediate Area of Being. Students J and K concurred with H. J saw even greater value in the report as a learning experience and noted the retention value of writing up data and analyzing it. This would suggest meaning in the Immediate Area of Being.

J stated that a good portion of the assigned mark given to a report should be based on the actual participation of the student as well as the accuracy of the data collected. This idea is in the Immediate Area of Being as it suggests the student is concerned with doing a good job with the required activity. All three students stated that the evaluation of their laboratory work had been fair. No further discussion arose concerning reporting and evaluation, indicating that it was of minimum concern.

The Laboratory as a Learning Experience

When asked their general opinion of laboratory work all three indicated that laboratory work was a break from the regular classroom grind which, K noted, was boring.

This suggests a meaning in the Immediate Area of Being. The students appeared not to view the laboratory work as much more than an imposed activity. However, J expanded on the meaning:

> J You get something by doing a lab. The material is explained to you in more detail than if you just read about it and did not experiment. You have a better understanding by doing. If you participate you understand more.

The opinion expressed appears to be in the Immediate Area of Being. The student sees the laboratory as a means for self improvement and greater understanding of the principles being studied. H noted that laboratory work with potential application outside the school is of particular value, and would indicate a meaning in the Responsible Area of Being. K stated that a good lab must hold your interest:

> K If you don't understand why something must be done, like some dissections, there is no personal involvement. Dissection labs were not good.

K does not apparently show any desire to take initiative in determining the worth of the dissections and suggests a meaning in the Passive Area of Being. When further questioned on the dissections both H and J indicated displeasure with the fact that once living organisms had to be handled and the working conditions included unpleasant odours. Their reponse also must be considered to be in the Immediate Area of Being.

K viewed outdoor activities as rating higher than indoor labs as the classroom setting can be left behind. J noted that since biology studies life, outdoor activities involved the real world and thus are of more value. Where K sees both classroom and outdoor experiences more in terms of the Passive Area of Being, J appears to give it meaning in the Immediate Area of Being.

H described a bacterial study and indicated it was a valuable experience because it revealed data on organisms which are normally not observable. This comment is in the Immediate Area of Being. K also stated that bacteria collecting didn't seem important and probably was not worth doing. This response is in the Passive Area of Being as it indicates a measure of boredom and disinterest.

The discussion turned to the influence of a teacher on the student's attitude toward laboratory work. H stated that a positive attitude on the part of the teacher increased student interest and the value of the lab:

> H In Chemistry, the teachers gave the impression of wanting to do the lab themselves. They were always moving around, helping. If the teacher likes doing the lab work it probably helps make it more fun.

H sees the teacher as the significant influence on her own attitude to the laboratory, not her personal interest in the subject. The meaning is in the Immediate Area of Being. J mentions that the main effect of the teacher has been to shift the emphasis from teacher centered activities at Junior High to more student centered responsibilities at the Senior High level. This suggests values in the Responsible Area of Being since the student is prepared to take part in the decision making process, within the limits of the laboratory situation. K had no comments about teacher influence.

When asked specifically whether laboratory work was of personal value K responded that she was not sure that science in general was useful, and found it hard to decide if there had been personal gain from the laboratory:

> K Something was learned from biology but not much. Not really wanting to learn is a problem. Biology was not very interesting.

K sees laboratory work as of value only if the subject matter or course is itself interesting. Labs are also of value mainly because they break up class routine and not because the activity is interesting. Since she takes no responsibility for the laboratory experience, K's meanings are in the Pasive Area of Being.

Although H and J agree that labs break normally boring class routines and thus are "fun", they note other more positive characteristics. The interaction with other students, freedom to talk and discuss, increased comprehension of the subject matter plus a "seeing is believing" effect are valued:

> H In lab activities you get with other people. You can talk. You learn something better also. In chemistry

> for example you can read about a reaction producing a coloured precipitate. If you can actually see it done it is better.

K You comprehend better because you see it, not just read about something.

Both students have values generally in the Immediate Area of Being. However in situations where real observations are made the students do make a decision on their acceptance of a teacher's or text's information which suggests the Responsible Area of Being.

The most popular activity in the snow unit appeared to be the snow shelter activity (quin-zhee construction). All three students concurred that it was fun to construct the quin-zhee and there were no problems in making it. The students all considered that the activity was valuable because of its potential usefulness:

H It was warmer inside. It was a valuable experience, especially with the winter conditions this year.

J It was warm inside, especially with people in it. It was about freezing. If ever you are stranded in the cold, you could build one to keep from freezing ... basic survival.

The students saw the activity as having a practical application to their own personal lives in an emergency situation. This indicates meaning in the Immediate Area of Being. If their concerns had included others, meaning in the Responsible Area of Being would also have been indicated. The students were then asked how they would have reacted to the unit if it had been taught entirely in the classroom without the actual investigation. K simply stated that it would not go over with a class if it was a classroom oriented activity without field work. To have value the lab portion was necessary:

J It could not be done. Being told the effects of snow on temperature would not help the student. The student must do the activity. This would increase understanding of how and when I got the results.

H The unit if simply learned in class as facts would not be as effective. Being outside doing it is better. It is more interesting when doing it by yourself and you pay more attention.

While H's comments are in the Immediate Area of Being, J shows some concern for making personal decisions. This comment indicates meaning in Responsible Area of Being. Both H and J considered that the snow ecology activities were the best lab experience to date, a worthwhile experience and that the unit had the qualities of a good lab.

K discussed the unit with some friends not in the class because it was an unusual type of activity and she had a good time doing it. She did not really see why this or other labs are being done. Labs are a necessity in order to complete course requirements. Labs have meanings to her that are in the Passive Area of Being. She did note that labs having information which could be of use at a later time had a higher value. This meaning is in the Immediate Area of Being.

Only J discussed the snow unit at home, but only because her parents' wanting to know why shovels had to be taken to class and the purpose of making a snow sampler. This indicates that the materials were not of sufficiently high interest to discuss them outside the school setting. This would suggest meaning in the Passive Area of Being. However, J agreed that the snow information could be useful in an emergency winter situation and that prior to studying the unit, using snow to help survive winter conditions would not have been considered. An altered view of snow in the winter environment had occurred. This indicates meanings in the Immediate Area of Being and borders on the Responsible Area of Being.

Although H was interested in the unit (Immediate Area of Being) it did not appear important enough to discuss outside the school situation. H saw the concepts learned as usable if stranded outdoors in winter. She was not sure whether similar survival techniques would not have been used in any case.

The students were asked to express their reaction if informed that they were to take a similar unit in another course:

H If a similar unit was to be included in Biology 30, it would be looked forward to. It would liven up the course.

This suggests a positive attitude to the unit by H and meaning within the Immediate Area of Being. H also noted that it was fun to do, provided useful information and would probably be the highlight of Biology 20. These meanings are in the Immediate Area of Being.

J reacted in a similar vein and added that outside activities were preferred to indoor labs. This indicated that interest in the activities are sufficiently high that a second study unit would be welcomed. These meanings are in the Immediate Area of Being. The outdoor activities were seen as involving the real world and as such indicate meaning in the Responsible Area of Being:

> J The lab activities are considered a good experience, interesting and providing basic knowledge. Other labs often have common knowledge you can learn. The snow unit had something to do with possible future use. Potentially useful labs are good although all labs can't be completely practical.

J recommended the unit as mandatory for Biology 20. The student sees the activities not only as personally valuable (Immediate Area of Being) but as being valuable to others (Responsible Area of Being).

K noted that she supposed if this type of unit was included in a future course it would be something of interest, but, referring to the cold, "It would also be nice to do in summer". The unit activities did not overly interest the student. The facetious remark about summer indicates that the physical discomforts while doing the lab were more important than the concepts illustrated or knowledge gained:

K Something of use was gained from the unit, unlike dissecting a frog which was not useful. Usefulness is good in a lab. You can't have labs everyday. Once in a while is good.

The meanings of the laboratory experience to K appear within the Passive Area of Being. Only suggesting the possible usefulness of lab work indicates any meanings in the Immediate Area of Being.

Description of Teacher Meanings, Class 2

Attitudes Toward Science Teaching

The teacher was asked to describe his academic background and why he had entered the teaching profession. He indicated that he initially received a degree in the sciences, had worked in the commercial field for a few years, then completed his B. Ed. at the University of Alberta. Teaching did provide some freedom to pursue other interests during the holiday periods.

When asked to express his opinion on teaching as a profession, he indicated that it has not been "too bad". It had its ups and downs. "I guess if you do something for eighteen years you must like it or you are stuck there". Smith does not appear to consider teaching an ideal occupation, thus his comments suggest meanings in the Immediate Area of Being.

The teacher was questioned on the subjects taught during his career. He indicated that they have included biology, drafting, sociology, geography and general science. Biology has always been one of his teaching assignments. Smith was certainly familiar with the Province of Alberta biology program and preferred to teach in this area. He also noted that to prevent teaching "stagnation", he likes to instruct in other areas since "something new keeps you going". This suggests meaning in the Immediate Area of Being.

Smith was then asked the extent to which the lab plays a role in his biology classes. He stated that although a reasonable amount of lab work is valuable, the need for preparation time reduces the amount actually done:

Smith Not as much as what is desired to what I think would be ideal. Lab exercises or proper lab experiences for students are difficult. They take a lot of preparation time on the teacher's part. I must honestly admit that I don't do as much as I should.

Meaning appears to be in the Immediate Area of Being. Smith went on to indicate that in Biology 30 he attempted about a dozen labs, which included both teacher demonstrations and lab experience situations.

Laboratory Organization, Instructions and Procedures

In order to initiate discussion on specific laboratory work, questioning was now directed toward the snow ecology unit. Smith was asked how the students responded to the unit:

Smith It was essentially generally favourable. Some of them of course are lazy. They don't like to go outside because they are inside types and

> because of that, regardless of how it would be set up, would not be really turned on by it.

Smith also added that students did not mind going out and he saw this as a response to classroom monotony. Both the teacher's and student meanings are in the Immediate Area of Being.

The teacher was asked how he had introduced the unit to his class:

> Smith The unit was introduced by giving the basic reasons for doing it, and generally what they would be expected to do. I had not really taken or had a chance to take the opportunity to figure out or read through the exercises to be able to tell them precisely what they would be doing. The first time through was like an opening night performance and you flounder from one experience to the next.

The teacher had not become familiar with the package of materials. Specific details on field techniques and sampling were not discussed in class. Familiarization with a lab activity allows for a more effective introduction to the topic in class. This suggests meanings in the Passive Area of Being. Smith noted that the package of materials provided was sufficiently complete so that a student who can read and think a bit should be able to follow the instructions and proceed with the directions given. Meanings are in the Immediate Area of Being.

Smith was then asked if the objectives of the unit were realistic, worthwhile and attainable in a lab situation:

> Smith Yes they certainly were. I think a number of students were surprised. They kind of had a feeling for their results, anticipating them. They were still kind of surprised at what they did get. The way the lab was set up certainly made them think in the direction desired. You know, the unit provided the questions in a directing sort of way which was quite useful.

Smith considers that the clear and surprising data as well as the directed questions in the lab results/discussion sheet contributed to the value of the snow unit. This suggests meanings in the Immediate Area of Being.

The teacher was then asked to comment on the usefulness of the predictions prior to collecting the data:

> Smith I made a mistake in doing that part of it. If I could do it again I would have them make the predictions before going out, then hand it in so they couldn't cook them up afterwards. Some of them didn't do their predictions until after and cooked them up.

Smith was questioned as to whether students often cook up results:

> Smith There are times they feel compelled to do this. If they are after marks, if conscientious, they don't have many reservations about cooking results.

Smith considers that correct data and correct answers to lab questions are highly valued by the students and generalizes that conscientious students who want high marks have some justification for "cooking" results. This suggests meanings in the Passive Area of Being, for both

Smith and the students.

When questioned on the organization of the unit, Smith referred to it as "pretty good". He thought that individual teachers, using their own styles and strategies, would probably wish to make some modifications. He felt that the lab report forms required thinking on the part of the student but that the data sheets should be part of the report (in fact, they were). Meaning appears to be in the Immediate Area of Being. He made further comments:

> Smith   The lab was fairly simple in concept. It might be used with some modifications to a Junior High Biology or Science. Some of them found it a bit simple, not elementary. It wasn't complex. It might be (used in Junior High) for further consideration. It's just a thought, for what it's worth.

Labs which can be easily modified to suit the teaching situation are of high value and have more value if they can be used at different grade levels with minor modifications. This suggests meanings in the Immediate Area of Being. Smith continued:

> Smith   Perhaps you could also go into heat loss, animal heat loss, and relate it to the number of calories required. Look at nutrition and how much energy food an animal has to consume in order to maintain body heat and this sort of thing. The unit can be extended. There is no end to this sort of thing.

Smith values lab activities which allow for expansion of the concepts and suggests meanings in the Responsible Area of Being. He agreed that the snow ecology unit exhibits most of the characteristics above and considered it to be well organized.

When asked about the time allotted to complete the unit, he replied that there was actually a lot of time to do it in:

> **Smith** We didn't need all the time allotted to it, which was good. Everyone can take it a bit easier. Generally though, when they are outside they tended to hurry as fast as they could because they were freezing. These city kids don't necessarily dress up even if you warn them. You tell them and they still don't dress up for the kind of weather out there and this year when the unit was done, it was pretty obnoxious. So the students were suffering and therefore did not really do what they should.

The teacher sees extra available time as valuable in that an activity does not have to be rushed. This indicates meaning in the Immediate Area of Being. His comments on student preparedness for lab activities suggests that his view of these students is in the Passive Area of Being. This is further illustrated below:

> **Smith** Outside the forgetfulness of the students it wasn't too bad getting it together. You still had to be on their backs. They tended to be reluctant. They would go out there wondering what they had to do. I would say that I told them what to do. You have to prepare yourself inside to know what you are going to do when you get out there. They stood out there wondering what they had to do.

Smith notes that students appear to be unprepared to plan work in advance of an activity, easily forget lab instructions and need continuous prodding to get them into an activity. From the teacher's point of view, this suggests student meanings in the Passive Area of Being.

Smith was then asked if he saw any value in students making some of their own equipment. He thought that having a full set of equipment ready to go would be preferable. Students took varying times to make the equipment and thus groups got out of synchronization in their outdoor activities. Smith mentioned that there were three or four students per group and felt that two or three would have been better. He also had a group of one:

> Smith — There was a group of one, a chap. There are loners. He wanted to work by himself and I let him. He did the first part but didn't turn in the second. He didn't bother to get around to doing the last part. Everything one day and "zilch" the next sort of thing. He didn't follow through. That is one of the problems of a long lab. They (the students) are hot and cold. They lose enthusiasm quickly.

Small group sizes are preferred by the teacher. Smith also assumes that it is the responsibility of the student to go through all procedures and complete activities in a lab situation. In addition the students are also expected to arrange groupings on their own. The teacher perceives these steps in terms of the Responsible Area of Being. His reluctance to keep his "loner" working or put into another group suggests meaning in the Passive Area of Being. He also sees less value in long term labs due to an apparent loss of student enthusiasm, a meaning in the Immediate Area of Being.

Activities, Assignments and Laboratory Evaluation

When asked about the value of the evaluation marking grig, Smith indicated that he had not used it. He then described the report and his method of evaluation:

> Smith I evaluated them on their report. They did a group report. One report was turned in per group to which they all contributed. There were two, three and four names on it. The marking reflected the numbers. If there were four in a group, I expected better answers to the questions from four heads than from two, so I marked accordingly. The entire lab was marked out of fifteen.

The teacher indicates that evaluation should be based only on the report submitted. Individual lab reports are not considered of particular value to the teacher. In Smith's opinion larger groups should prepare a better report than a small lab group. The teacher was not familiar with the suggested marking grid. These suggest meanings in the Immediate Area of Being.

The value of the reading assignment was then questioned. Smith reported a favourable reaction to it on the part of the students. He did note that some were using the two articles as aids in completing the results/ discussion sheets for the last activity. The teacher also felt that because "true" research relies on previously written materials, the use of readings in an activity tends to reflect characteristics of a real investigation and that it should certainly be part of the snow unit. This suggests meaning in the Responsible Area of Being.

It was hoped to return to this topic as it appeared to open up a number of items for further discussion. Unfortunately, time constraints terminated the interview before additional information could be obtained.

The Laboratory as a Learning Experience

Smith was asked about the value of laboratory work in science courses:

Smith Lab activity has to be quite well thought out to get the most out of it. In the past we have been doing labs that are cookbook things. They don't give the students really a great learning experience; simply a verification of things. Students have mentioned that if they could have done it as a handout they would not have had to spend a half-hour learning on their own. But there are learning experiences that go on in a well thought out lab that are of value. It's the only way to get it.

Smith suggests that a lab must be well thought out and not a confirmation activity to have value in terms of the students and the teacher. Meanings would appear to be in the Immediate Area of Being. He also indicates that verification labs seem to waste course time and that the students prefer a handout to learning on their own, an indication of total disinterest in the material and implying meaning in the Passive Area of Being.

Smith was questioned further on the laboratory experience. He was asked to describe what he considered a well thought out laboratory activity:

Smith	One which requires a student to innovate, to perceive or get results and be able to interpret results and draw conclusions. This will provide a satisfying experience to the students.

The teacher feels that labs involving higher levels of thinking will provide students with a satisfying experience. He was then asked how he determined whether or not it had been a satisfying experience:

Smith	That's difficult. I suppose from the writing up of a designed lab report where a series of questions are to be answered. The student has to think about the lab experience and analyze the lab to come to the right answers to the questions.

Smith states that the lab report, with designated answers to predesigned questions, can reveal student satisfaction with the activity. The report must require the student to analyze the data by means of answers to the questions. This suggests meanings in the Immediate Area of Being. The teacher apparently is not an advocate of enquiry activities.

His comments led to a question on lab report evaluation. Smith noted that students' abilities to think in an abstract manner, to apply, interpolate, and analyze results differ considerably. Some students cannot do this. They are lost and frustrated. They have a bad laboratory experience. The implication is that students who are unable to work at higher levels of learning should probably not take part in this style of lab work to prevent frustration. This suggests meaning in the Immediate Area of Being on the part of the teacher. The teacher sees student meanings in the Passive Area of Being.

Smith was asked if he ever obtained student feedback on the worth of labs:

> Smith Yes. During a lab you try to stand back or try to listen to what is going on. If you are open with your students to start with you have an open sort of climate. They don't feel restricted in displaying their displeasures or lack of useful experiences. In that way you can "read" what they are getting out of it; whether the experience is useful or not.

Smith sees an open, free classroom situation as allowing for effective feedback from the students which would indicate meaning in the Responsible Area of Being. The feedback noted tends to be of the negative variety. This suggests meanings for the students in the Passive Area of Being.

Smith was then asked whether he could cover the same concepts as regular classwork rather than as lab activities as effectively and efficiently:

> Smith I think a lot of the present lab experiences we do, and I am being critical of myself here, are not of the type where the student can really apply this gained knowledge; apply or extrapolate, synthesize or, in other words, draw conclusions and use advanced mental processes. Yes, I would think that a lot of exercises we

> do in our schools could be done more effectively and efficiently if time means anything. It would be simpler to cover it in lecture or film.

Smith indicates that classroom teaching involves less preparation than lab activities and that many of the presently used lab exercises result in lost teaching time since the content and concepts could be presented as effectively during classroom instruction. This suggests meaning in the Passive Area of Being. Although he expresses concern with student acquisition of higher learning skills, no definite suggestions are given for changes to the present lab program. This suggests meanings in the Immediate Area of Being. To further clarify this point he was asked whether there were any time constraints in teaching the various biology courses:

> Smith In some courses this is so but not necessarily in Biology 10 or 20 where there is time to do a lot of lab activity. But then again it takes organization to set up these labs in such a way that there is a lab experience.

Excessive course content is seen as deterring from time spent in the lab but when time is available, preparation time appears to be a negative factor. These meanings are in the Passive Area of Being.

Smith was now asked to express his opinion on the elimination of the lab from the science program. He indicated that the lab is essential for science programs because it introduces the students to the lab environment and the handling of equipment. Meanings are in the Immediate Area of Being. However, many topics could be taught in a classroom more efficiently than in the lab. Students can be lectured on how to do lab type activities. This suggests meanings in the Immediate Area of Being, as the teacher does not consider that the effectiveness of experience is of more importance to the student than the time saved by a classroom presentation.

The teacher was asked for his overall reaction to the snow unit. He thought that the nature of the Canadian environment was such that activities such as those in the snow unit were highly desirable in terms of the ecology of organisms. Lab activities which increase awareness to natural situations are of high value. Reading scientific articles was also of high value. This indicates meanings in the Responsible Area of Being. The teacher stated that he was quite impressed with the unit but he would probably want to make a few small changes to suit his teaching style. Examples were more specific objectives, and instructions for each activity.

Smith was asked if he saw the snow unit as fitting in the Biology 20 program:

> Smith It is certainly part of the ecology of living things in this part of the world. If you are going to be realistic about the study of ecology, if it is important to study local conditions, then it is certainly important to do that type of activity.

Since winter is part of the natural environment, the teacher feels the unit is of considerable importance as a learning experience for students. This suggests meanings in the Responsible Area of Being. Smith was asked to give his reaction to having the snow unit as a mandatory part of the Biology 20 program. He thought it would be useful. He saw the lack of texts with background information for teachers and students as a possible problem. A small group investigation would be the best method of attack. He also saw another way of dealing with the activities:

Smith This would be good homework. They can do it in their backyards. They don't even have to do it at school. Some of the equipment, such as the thermometer, might be a bit of a problem, but it is not insurmountable. They can do it at home in their own backyards at their own choosing.

Labs which can be done outside the school setting are of value to the teacher who prefers labs that require little or no supervision. The students would assume maximum responsibility for their completion. This suggests meanings in the Immediate Area of Being.

Smith was questioned on possible application of concepts studied in the snow unit to everyday life. He had the impression from watching them work outside that they had hardly ever been out in the winter:

Smith They were pansies. They didn't go about it in a thoughtful organized way. They sure need a lot more of this type of lab activity or whatever. They weren't dressed properly so they were cold. They chose site A and B which were not average or representative.

> They sort of randomly fell into the snow. That was disappointing.

He also noted that a few, not necessarily the best academically, went about the activities in a more organized way. He then continued:

> Smith Application? I suppose. I guess there were those who do skiing and so on in the winter. They can relate to different snow conditions. They are more aware.

He considers that the application of lab material outside the classroom may have some possible value. His main concern however, is the general disorganization of the students when in the field. However, he apparently gave them no definite direction, relying on the instructions in the unit to clarify situations, which indicates possible weakness in the instructional package. This suggests meanings in the Immediate Area of Being.

Thinking, analyzing, and drawing conclusions were characteristics Smith had indicated as desirable in a lab activity. He was asked if the snow unit had allowed students to do these things:

> Smith Yes. The questions they had to answer at the end of the exercises did make them arrive at this kind of thinking; what they should be getting out of it. So it was done anyway.

Smith's indication of satisfaction suggests meanings in the Immediate Area of Being.

The teacher concluded the interview by indicating that the snow unit was of sufficient value to the students to be definitely included somewhere in the curriculum, suggesting a meaning in the Responsible Area of Being. He noted that the knowledge gained was of use to the students and the unit fit into his criteria of a good lab experience. If the unit was to be a regular part of Biology 20, he hoped that some of the questions would provide more of a challenge to the students. The work itself was not too difficult for students at the Biology 20 level. His meanings appear to be in the Immediate Area of Being.

Summary of Students and Teacher Interpretations, Class 2

This summary includes items which provide alternative or additonal interpretations from those described in the summary for Class 1.

Passive Area of Being

One student indicated her opinion of the laboratory reflected her general lack of interst in biological science. This unit was done because it had to be done although some interest was indicated. It was thought that the teacher should explain most of, if not all, the procedures for a lab in class, in order to reduce or eliminate the necessity of reading instructions. The required recopying of field data when preparing a formal report was not appreciated by one student in particular. It was done once. Why do it again?

The teacher had not taken time to become familiar with the materials in the unit or discuss procedures in class. The students were given the packages and left to themselves to organize and handle the activities. The teacher had observed one student doing the work on his own, getting discouraged and failing to complete the unit. Smith noted that some students are lazy, would never get enthusiastic about lab work and maybe should not do any. He observed that frustration on the part of the students, when they become confused with procedures, had a negative effect on their work. Some students were observed to "cook" results in order to get better marks and he thought that for the better students, faced with external pressures in entering advanced courses or post secondary institutions, it may well be justified.

Smith felt, in general, that labs required too much preparation time and that as a result his classes performed less than an ideal number of activities. All participants felt that the homemade equipment led to frustration because it required construction and did not function well.

Immediate Area of Being

Although some teacher presentation was desired by the students to clarify problems and potential difficulties the teacher thought that a self-contained lab exercise could be handled by students if it was well designed. A lab had to meet its objectives adequately, which had been the case with the snow unit. Some labs and lab techniques could be illustrated in class without the need for a student laboratory. The students emphasized that it was important to clearly understand the purpose of an investigation before proceeding with the work. Lab groupings were preferred for sharing the work load. The use of "professional" equipment for the ease of measurement and more accurate results was mentioned by all participants.

The teacher required a single group lab report and equated a better report with a larger group. The students thought that some reward for effort and data collection should be given. The teacher however considered the discussion of data and answers to questions as having the greatest weight. He also noted that the unit could be done at home since little teacher supervision was necessary.

Responsible Area of Being

The students noted that doing work in the outdoors was in the real world of most living things. The teacher stressed that the unit had real meaning to the students because it exemplified a real Canadian situation and that it had a place in biology programs. The students thought the unit should be compulsory for Biology 20 students and would be a valuable experience to anyone. The unit was thought to characterize their opinions on the values of a satisfactory lab experience.

The teacher considered that, as a part of their training, the students should take the responsibility for organizing specific lab groups and the work load within each group. Reading scientific articles for exposure to scientific communication and writing styles was considered important. He felt that the laboratory experience was essential, particularly for learning techniques which they might require in the future. He also noted that surprising or unexpected data seemed to result in better thinking when the students drew conclusions from the experience.

Both students and teacher were prepared to suggest ways of making the unit more meaningful to future participants. In particular, the students recommended that the ambient temperature at the time be used as the basis of temperature predictions. This would make the situation more realistic, accurate and effective. They also noted that without the activities the unit would have been nearly useless as a learning experience.

Description of Student Meanings, Class 3

Background in High School Science

The eight students interviewed were asked to describe their high school science background. Q had taken all three sciences at the Grade 10 level, R and S had taken biology and chemistry while T had taken only biology. Both L and M had completed Biology 10 and Chemistry 10. L had also taken Chemistry 20. N and P had taken Chemistry 10 and 20 as well as Biology 10. P had also completed physics at the grade 10 and 11 levels. The students also indicated familiarity with laboratory work in the sciences. Chemistry laboratories had involved weighing, making solutions and observing chemical reactions. N described dissections as a biological activity while P added work with the microscope. The other students concurred. P stated that there was little laboratory work done compared to classwork. Both students were naturally interested in biological science and had selected Biology 20 for this reason and as a potential requirement for entering university in the future. Biology as a science has meanings in the Immediate Area of Being. Q, R and S indicated they had elected to take Biology 20 for both matriculation purposes (Q, R and S) and for interest (R, S and T). T selected biology exclusively because of interest and the possible application of the materials learned to everyday situations in life. This suggests meanings in the Responsible Area of Being. L chose Biology 20 in order to work for university entrance requirements, while M chose Biology 20 for possible use in entering a veterinary medicine program and because of personal interest in the subject matter. Both students indicate meanings in biology in the Immediate Area of Being, respectively. In addition M said that biology was of value because it related to out of school situations.

They were questioned on the types of snow activities that they had been involved with in the unit. All the activities were mentioned. These included the necessity of going outside to record temperatures in the snow. The increase in temperature with depth was observed. Student N noted that his father had used snow to insulate around the milk house and now knew why it was used. This suggests meaning in the Immediate Area of Being.

Laboratory Organization, Instructions and Procedures

The students were asked if they had read the laboratory instructions prior to the first two activities:

> L The introductory reading was skipped through; the assignment reading was done. There was no difficulty with the reading level. The instructions were clear. These were read while in the field.

This would indicate a meaning in the Passive Area of Being. L added that there were no problems in making the snow testing equipment.

M read only what was necessary at the time. Although the reading level was fine, too much would have been forgotten if everything had been read at one time. This suggests meaning in the Immediate Area of Being. N did not feel it necessary to read everything. The material was well organized and easy to understand. P concurred and said that the equipment was easy to make. There were few problems in setting up the snow station. Both students agreed that clear instruction and good organization are valuable characteristics of a laboratory. These are meanings in the Immediate Area of Being.

Q thought that the reading materials were not too interesting, probably because of his indicated dislike for reading in general. This suggests meanings in the Passive Area of Being. R liked the idea of developing a background prior to an activity and stated that the laboratory instructions did this quite well. S said that the general class discussion before each activity clarified any problems in interpreting the activity instructions:

> T The materials were quite readable. With concentration you could understand it all. The descriptions for snow terms, for example, were spelled out clearly.

T was prepared to put out the extra effort to be sure the materials were understood. This suggests meanings in the Responsible Area of Being. T continued:

> T The interest level is considered really good. Information was provided to arouse your curiosity and make you want to find out more. Then it would tell you - here is a lab to do to find out more. Therefore it was found to be interesting, not something one started to read and found boring and put away. It kept up interest.

The meanings expressed by T indicate the Immediate Area of Being. The student is depending on the reading material to maintain interest. Nevertheless her stress on wanting to find out more suggests some meaning in the Responsible Area of Being:

> Q If instructions were read there would not be many problems in equipment construction. The snow sampler was not

well constructed.

The indication is that Q had not taken the time to prepare herself for making the snow sampler. It was made only because it was required, suggesting meanings in the Passive Area of Being. S noted that diagrams were valuable to aid laboratory instructions, and that class instructions often helped clarify a point and are important to lab procedures. Meanings are in the Immediate Area of Being. T also mentioned the value of diagrams in laboratory instructions, where applicable.

The discussion centered on the first outdoor activity. M indicated that the very cold weather was a problem but not the activities themselves. L agreed and added that it would have been nicer if it had been warmer but it was not really cold if one came prepared. This indicates meaning in the Immediate Area of Being.

Both students predicted a warming trend under the snow:

> M — It was quite warm closer to the ground, under the snow. At 5 cm above the ground it was -8°C. The air temperature at the time was -22°C.

L noted that his measurements differed in part from those obtained from the rest of the class. Both liked the idea of predicting beforehand as it provides you something with which to compare data. This suggests meanings within the Immediate Area of Being.

Q thought that predicting results prior to the activity produces a more effective data collecting experience. The temperatures in the snow were warmer than predicted which was surprising. S had predicted no change and was "shocked at the results". R's predictions were not even close. It was warmer than predicted. T thought it would be colder under the snow. The students in general felt that predicting results in advance makes the actual results more significant. This suggests meanings in the Immediate Area of Being. P found them of little value. N thought they were a guess at best since the actual air temperature was not known. If real values had been used, the prediction section would be more valid and useful. The meanings are in the Responsible Area of Being.

The students were asked to react to the thought of going outside into the cold for the first activity. R, Q and T were not too enthusiastic and did not like the idea of freezing. S thought it would be fun to go outside. They became interested in the work and all stated that, as a result, the cold became much less significant. This suggests meaning in the Immediate Area of Being. Interest appears to overcome justifiable objections to the working environment.

The students were expected to have read and understood the instructions before going into the field so that they would have to concentrate only on their work and recording the data. They were questioned on whether this had actually been the case:

R The data sheets had places for recording all the required information. This made things easy because it was so cold out. There were no difficulties remembering the lab instructions because there was not that much to do at one time.

T The data sheets spelled out the order of the data collection. Interpretation of the data was made much easier. If personally designed data sheets had been made the data would probably have been poorly organized and difficult to interpret.

Students S and Q simply stated that if the instructions were read over a couple of times there were no problems remembering the field instructions. None of the students indicated meaning other than in the Immediate Area of Being.

The students stated that the second outdoor activity proceeded with minimal difficulty. The instructions were clear and the data sheets appropriate. Both N and P found some difficulties determining the age of the snow crystals. The hand lens used was ineffective. P said that her group put down any age that seemed reasonable. Unless the equipment functions properly, meanings appear to be in the Passive Area of Being. L and M both had difficulty in locating their snow stations due to a heavy snowfall which had occurred the previous evening. M suggested that marking flags would be valuable to everyone involved. This suggests meaning in the Responsible Area of Being. Neither student viewed the problems encountered as more frustrating than real or naturally occurring, suggesting a view of the activity in the Passive Area of Being:

> L Three layers of snow were observed. Temperatures were checked and samples were taken of each layer for density calculation. The snow crystals were aged more easily than expected. The snow sampler broke because of poor workmanship. Harder upper layers seemed older than layers underneath. Each group member did a specific job on the snow density data. One scooped, one weighed the sample and one recorded the data. This made it easy.

L notes that organized teamwork is a valuable part of a laboratory experience. This indicates meanings in the Immediate Area of Being. M was able to collect distinct data readings and considered that this made the laboratory more effective. Functional equipment increased the value of the laboratory. M mentioned that the snow sampler gave problems. Meanings appear to be in the Immediate Area of Being. Both students indicated that the concepts of stratification, age and density were easily understood and, although the weather conditions were poor, were quite prepared at this point to do more outdoor work. Proper clothing plus interest in what they were doing eliminated the weather as a major negative factor. The high interest level in adverse conditions would indicate meanings in the Immediate Area of Being. As M stated, "I'm getting used to it". M suggests that a pleasant environment makes laboratory work more enjoyable, a meaning in the Immediate Area of Being.

The students stated that things were easier to do because experience with the techniques had been gained during the first exercise. A laboratory which utilizes previously learned techniques is valued by the students and suggests meaning in the Immediate Area of Being.

Based on problems encountered by the group, M suggested a modified technique for taking snow temperatures. M had observed others having the same problems. This indicates meaning in the Responsible Area of Being.

The third outdoor activity required the construction of a quin-zhee or snow shelter. P stated that it had taken two days; one for piling the snow and the other for digging the pile out. N said that two days were required because of the timetabling of three credit courses:

> N The snow would not take two days to set. This was because of the every second day arrangement. It would probably take about half an hour to set on a very cold day according to class information.

N noted that a cavern was dug out and temperatures inside and outside were recorded:

> N It was quite warm in there. If you were in the north you could probably survive with one of these things because of the insulation of the snow.

N does not see the quin-zhee as having value in the local area, only the north. He does indicate a preference for an activity with practical overtones. There are meanings in the Immediate Area of Being.

L and M indicated that the instructions were clear, and only the small size of the shovels slowed down L's group. This indicates that less than satisfactory equipment reduces the value of a laboratory and limits its meaning to the Passive Area of Being.

S was now questioned on the time taken to pile the snow, to wait for it to set, then to hollow out the pile. He thought it had taken only about one hour in total. He was asked whether it should be done that way in the unit, rather than splitting the steps over two days:

S Digging out the quin-zhee the same day as piling the snow would be more realistic. For what the exercise was trying to illustrate it would be better to leave the instructions as is.

S prefers to get definite results which can be easily analyzed. This indicates meanings in the Immediate Area of Being. T thought that it might have been done in one period. Q thought that having successful results was probably due to the two days involved and that it was more important to get good data than have a more realistic situation. R agreed with this idea. This suggests meanings in the Immediate Area of Being.

No problems were encountered in building the quin-zhee. Temperatures had generally risen to the 0°C range. Q mentioned the effect of the closed door and body heat on temperature elevation, and thought that additional people in the shelter would affect the temperature even more. T stressed clearing the inside floor of snow to insure that heat from the ground could warm up the interior. The students used the previous concepts investigated in these descriptions. Their meanings are in the Immediate Area of Being.

M obtained data which appeared useful beyond the specific laboratory activity:

> M It was a lot warmer inside when a couple of people were in with the door closed. Within six minutes it was +2°C. With more people inside and a longer time period the temperature would possibly have been a lot warmer. Maximum temperatures might reach +10°C because the quin-zhee was quite thick; especially if there were two to four people inside. It might even get too warm.

M has become well aware of the concept of snow insulation and body heat generation. This suggests meaning in the Immediate Area of Being, as no indication was given of using this information beyond the self.

L suggested that a small fire might be effective in warming up the shelter if only one person was in it. S noted that the door would have to be open to prevent suffocation. He also thought that the shelter could be constructed using only hands and that the idea of using snow in this way had not occurred prior to having done the unit. This also gives meaning in the Immediate Area of Being.

M thought it would be quite interesting to camp overnight as part of the unit but recognized the difficulties involved. The quin-zhee would be easy to construct if stranded. She thought that it would be fun to do it at home. These thoughts are within the Immediate Area of Being. The students appeared to be indicating that open ended investigations are both desirable and valuable, meanings which may be approaching the Responsible Area of Being.

N and P provided further information. N considered the activity fun, better than staying in class, meanings in the Immediate Area of Being. P described her experience with the snow shelter:

> P You noticed the smallness, the warmth and the lack of sound from the people outside who had to yell like crazy to be heard throught the snow. There was no wind inside. It was very windy outside and this made it feel warmer than it was. With two people inside the temperature was +1°C. If more time had been spent inside it might have reached 7°C to 8°C. If you had the equipment it would be interesting to measure sound and stuff like that.

Laboratories which produce easily observed effects have value to the student, with meanings in the Immediate Area of Being. The suggestion of specific topics for further investigation indicates meaning in the Responsible Area of Being.

N's group decided to investigate further having completed all the required measurements. A third person entered the quin-zhee and additional temperatures were recorded. The temperature rose from 0°C to 2°C. The meanings of this student initiated activity are in the Responsible Area of Being. Personally experiencing a situation is of value to the student, better than second-hand learning. The practical application of the exercise was noted, indicating meanings in the Responsible Area of Being.

The students were surprised and impressed with the strength of the quin-zhee when it was time to break it down. The change in the snow from soft powder to crystalized hard pack, sufficient to temporarily withstand three or four students jumping on the roof, had a considerable effect. This gave the experience added impact because of the unexpected results, providing meaning in the Immediate Area of Being.

The students had no changes or suggested any improvements to the basic unit. They all felt relatively comfortable with the unit as it was set up. The time allotment was thought to be quite satisfactory. R mentioned that there was even time at the end of an activity to start work on the results/discussion sheets. Having sufficient time to complete work was considered a characteristic of a good laboratory. This suggests meaning in the Immediate Area of Being.

Activities, Assignments and Laboratory Evaluation

The students were questioned on the required laboratory report for each activity. They considered the result/discussion exercises as straightforward. T stated that for such things as graphing, the book gave clear instructions and models.

M thought that although the questions were at a reasonable level of difficulty the answers were probably written in less depth than they should have been. It was suggestsed that more guidance on this matter was required by the students. This suggests meaning in the Immediate Area of Being. S thought that a lot was learned from answering the questions:

> S Some of the answers were obvious but others you had to think about; put yourself in the situation then answer. For example, the effects of a heat source in the quin-zhee other than melting. Had to think.

S considers that greater learning results from having to do more than answer simple questions. He appears to have meaning closer to the Responsible Area of Being since he sees the value of being challenged.

The students were asked about the necessity of laboratory reports. A lively discussion resulted. All agreed that they should be required. R thought the nature of the laboratory might determine whether a report would be necessary. Q noted that the report is a measure of what is learned. T stresses that the effort put into the activity should be included in any marking scheme. These meanings are within the Immediate Area of Being.

P thought that a report permitted the teacher to evaluate students' work and gave the student an opportunity to clarify the data collected and the material learned. N agreed. He noted that a higher percentage of a laboratory report mark should be based on a student's ability to use and understand the data obtained. Since data can be copied, marks assigned to the actual collection of the data should be limited. Some recognition should be given for effort to help students who do all the work, and try hard but have difficulty understanding concepts. These meanings are in the Responsible Area of Being. Like N, P felt that marks had to be given for effort during the activity as well as on the analysis of the actual data. Both students mentioned a reward (marks) for doing a lab was necessary, indicating meaning in the Passive Area of Being. M added the following comments:

> M A report of some type should be turned in, even if it is only the data collected. There are people who do not do a lab. Why should you put a lot of work into it and get nothing out of it; except seeing the results. You could have read it in a book in less time. You should hand something in.

In the sense that M does not see she is in control of her own learning experience and can determine her own personal gain from the experience, the meaning is in the Passive Area of Being. However, in terms of protecting a student's effort from those individuals who do not participate, the meaning is in the Immediate Area of Being.

P was concerned that the data collected might lead to incorrect conclusions yet be correct for the data itself. Both S and L agreed. L further stated that a laboratory mark should not be based on whether data is right or wrong. L correctly indicated that there were so many factors involved in an experiment that data, as such, are correct. These are meanings in the Immediate Area of Being.

The questioning turned to the reading assignment. The materials were readable and the assignment which followed forced reading in more depth. M thought that since both articles covered similar material, reading one would have been sufficient. The meanings of the assignment to the student appeared to be in the Passive Area of Being. M added that detailed reading was necessary to complete the blanks and this was of greater value than one which required a minimum of effort. This suggests a meaning in the Immediate Area of Being. N said that the articles would only have been read lightly but that the assignment which followed (fill in the blanks) required considerable work and made one read the articles pretty thoroughly. This suggests meanings in the Passive Area of Being. P found the articles interesting but, like N, required the assignment to initiate reading in depth. S however, expressed a contrary point of view:

> S Because questions followed the reading assignment you had to concentrate much more on the readings. Even if there had been no assignment they would have been read. My curiosity had been aroused and the articles were worthwhile reading.

Although S has a personal interest in the articles he does not consider them of sufficient importance to get others to read them. This suggests meanings in the Immediate Area of Being.

The Laboratory as a Learning Experience

When asked what he considered a good laboratory, Q used the word "challenging". T agreed and suggested that it made you "dig deep" to find the information. This indicates meanings in the Responsible Area of Being. N did stress that a good lab was one in which a person understands what was being done. Very clear aims and instructions were necessary. Teachers should demonstrate the use of any unusual equipment. Poor technical equipment reduces the value of a laboratory. These meanings appear to be in the Immediate Area of Being. L finds laboratory work an enjoyable method of learning but notes that the danger factor in some investigations detracts from their effectiveness, a meaning in the Immediate Area of Being:

> M It allows you to see if things really happen; if it's true. You try it yourself. It's not the same as reading about it in a book. The only disadvantage with lab work is the time required.

Student M views laboratory work as having meanings within the Immediate Area of Being. She hopes that an experiment turns out the way it is supposed to. If not, it must have been done incorrectly. This indicates meaning in the Passive Area of Being. L prefers a minimum of teacher supervision, a meaning in the Responsible Area of Being.

He also values a laboratory if it relates to the course and sufficient time is given to do it properly. L concludes that a good laboratory must be interesting and allow the student to get involved with the topic. Good instructions and diagrams, where required, add to the value of the laboratory experience. These meanings appear within the Immediate Area of Being.

When describing their general laboratory experiences, S and T made the following comments:

S The labs done were worthwhile. More was learned in the lab than would have if simply classwork, such as note taking. It was fun and change form class routine.

T Lab work is enjoyed. A lab is fun. You get to see things for yourself, not just be told about them. There is certainly value in doing labs.

Q and R agreed with S and T. These meanings are in the Immediate Area of Being. Comments on "seeing is believing" tend to indicate meanings in the Responsible Area of Being.

The value of having a laboratory partner was discussed by P:

P Partners are good to have in lab activities. If you are not sure if you are doing something right you can check with your partner. It's better when you need another hand or something. The size of a group depends on what you are doing. If it is too large you have people doing nothing, just standing around watching.

P shows concern for the actions of others and a willingness to use personal initiative by discussion problems with other students rather than the teacher. Meanings are in the Responsible Area of Being. N added that in microscope work, a one microscope per student situation would allow everyone to maximize their learning. This has meanings in the Responsible Area of Being.

The students were asked to give their opinion on the amount of time they would like to see assigned to laboratory activities in their next biology course. L and M indicated that 60% would be ideal. When asked to explain why, L stated that the laboratory work was more interesting than reading the text or classroom discussion. First hand experience is gained, which arouses greater interest and the retention of information for a longer period of time. M gave similar reasons for her choice. Meanings are in the Immediate Area of Being. N thought that about one-third of the time should be in the laboratory:

> N The amount of basic information you learned would be less than having more classwork but you would understand better. By making notes you know more but when you do one thing in a lab you understand it well; you are not going to forget it. When you take notes you take them and forget it; well, you don't; you write it down on an exam but down the road two or three years, you probably forget it. If you did it in a lab and did it all and understood it, you would probably remember it for a long time, a very long time.

N sees considerable value in doing laboratory work, in terms of both learning and remembering. His indication of a need for laboratory experience in a course has meaning in the Responsible Area of Being.

P notes that time to cover course work, especially in Grade 12, is always limited and that the laboratory uses too much time for the learning gained. The student would rather spend more time on class notes, thus reducing laboratory time considerably, along with homework. Meanings here are in the Immediate Area of Being. The student does not view the laboratory as a necessity in a science program, even if there is more gained out of a well set up laboratory than straight class work.

The students were then asked if they could have learned the materials just as effectively by studying the concepts in the classroom.

L preferred to do the activities, especially since they were outdoors:

L It "holds more water" to find out for yourself rather than someone simply telling you the facts. First hand observations are preferred to relying on someone's work regardless of their qualifications.

Laboratory work to L offers breaks from class routines (Passive Area of Being). However, self determinations of the validity of concepts indicates decision making by the student. This meaning is in the Responsible Area of Being:

M The material learned in the field sticks in the head longer if it is experienced. It's more effective. Even the Brownies and Guides motto says something about "learning by doing". In an 80 minute period you just get told and told. The mind wanders off.

> Going out and doing makes it stick in your mind.

M's meanings for the laboratory experience are in the Immediate Area of Being. R added further to discussion:

> R Lab work is necessary because it shows you everything. This could not be done if it was just normal classroom work. The snow station is an example. I didn't really think there were any temperature differences in the snow. The lab sure showed it was a lot warmer under the snow. You really wouldn't realize that unless you did it. You do it yourself and you learn to do it yourself. This is better than a demonstration.

R's concerns have meanings in the Responsible Area of Being. The other students had similar responses. N continued in a similar vein:

> N I would sooner get out and examine it for myself. The teacher can lecture for 80 minutes and you can write all the notes you want but it doesn't mean you are going to know it. If you do out there and do it you can remember. You remember because you did it yourself; that the farther down you get toward the soil, the warmer it actually becomes. It was good to get out there.

To N the laboratory is a valuable learning experience. Personal satisfaction is involved. His reflections do not indicate an extension of his ideas to others in the same position. His meanings are in the Immediate Area of Being. P took a contrary position and considered that it took too long to do very little. Snow insulates. It's common sense. To her the activity had meanings in the Passive Area of Being. However the field work was enjoyable.

Asked if teacher attitude had ever influenced their own laboratory attitude, Q thought that if students felt that the teacher didn't know what he was talking about, the laboratory would probably be a waste of time. The meanings are in the Immediate Area of Being since the student does not indicate the value of the laboratory experience as of greater significance than the teacher's attitude:

> T If a teacher has a negative attitude toward a lab, you get it also. They seem to be saying that the lab is in the curriculum therefore must be done but it's no use for us. But it must be done. Your attitude is therefore, "Oh great. Another lab to do for doings sake and not for getting anything out of it."

T sees the teacher as having meanings in the Passive Area of Being but does not indicate she is herself that much different. Her meanings also appear to be in the Passive Area of Being.

When asked if they saw any value to having done the unit R indicated that it showed how animals could survive by burying in the snow to get where it is warmer. T thought that most people think of snow as a problem, such as having to shovel it. It is now seen that snow can be beneficial in some ways. S agreed. This suggests meanings in the Immediate Area of Being since there was no indication of the desire to involve others in sharing the benefits of their knowledge. P thought there might be some practical applications made of the information learned and mentioned that the Inuit had put it to use. N thought there might be some application in the control of avalanches, as in Jasper Park. Meanings appear to be in the Immediate Area of Being. L said it would seem possible to use snow as a shelter against the cold if stranded in the winter. This suggests meaning in the Immediate Area of Being. M agreed and extended the concept to on the job situations, such as pipeline construction. This would indicate a meaning in the Responsible Area of Being. Both students value laboratory experience with some practical application outside the classroom.

M mentioned that learning occurred in a more interesting way, and that the knowledge also might prove useful in an emergency winter situation. L agreed and stated that he had discussed the unit at home. He also indicated that he felt his attitude had changed toward snow, from it being a nuisance to having more importance. These are meanings in the Immediate Area of Being.

M described the application of the unit to everyday life as in a survival situation:

> M This was not obvious until all the work had been done. Before doing the unit I thought I would probably freeze to death in a survival situation. It had always been assumed it was warmer on top on the snow rather than under it. I would have sat in the car and frozen.

M's comments indicate meanings in the Immediate Area of Being. She continued by mentioning that the unit had been discussed at home a number of times, particularly the temperatures recorded under the snow. She described the quin-zhee construction method to her brother who proceeded to build one. Her concern and involvement in the unit at this level indicates meaning in the Responsible Area of Being. M also indicated a more positive attitude toward snow in winter and a desire to do more work of this type.

The students were asked to react to the knowledge that a similar unit would be done in Biology 30. T said she would look forward to it:

> T A lot has been learned so far. In another course you could become more aware of factors you hadn't thought of, that never even occurred to you that actually exist.

R and S thought it would be good but S qualified his answer by stating that he doubted there would be much more to be learned, indicating a desire to be exposed to new materials rather than repeat for greater understanding. Q agreed and thought it would be easy to get good laboratory marks. This suggests meanings in the Passive Area of Being. T, however, sees value in expanding her knowledge and her meanings approach the Responsible Area of Being. N was positive, indicating again that a break from class routines and experiencing a real situation was desirable. He also indicated that the social interaction of the laboratory group was important. These meanings are in the Immediate Area of Being. P thought the idea was fine but did not elaborate, possibly indicating a meaning in the Passive Area of Being. M thought she would like to do it again and L said it would be enjoyable. These meanings are in the

Immediate Area of Being.

The students were asked to rate the snow unit. N thought it rated eight on a scale of ten. The reasons given are as follows: the activity took place outside the classroom itself thus breaking boredom; the activities took place in the real world; the activities were enjoyable; the activities provided information and techniques which were seen as practical considering the Canadian climate. The first three are meanings in the Immediate Area of Being. The final point is in the Responsible Area of Being. The time allotted to the unit was sufficient.

P rated the activities as average. She thought that most people were already aware of the concepts investigated and that repetition is a waste of time. On the other hand she had never done field work before. Her meanings are in the Passive Area of Being. P agreed that the time available to do the unit was satisfactory. L and M rated the snow unit as reasonably interesting, L from the point of view of breaking up class monotony (Immediate Area of Being) and M in part due to the perceived usefulness of the knowledge gained (Responsible Area of Being). R thought it was done in more depth than any laboratory he had done. It involved more extensive work and as such was rated as an eight or nine on a scale of ten. An in-depth study is considered of high value by the student. S said he was very critical of laboratory activities and that he would rate the laboratory at seven or eight since he got a lot out of doing it. Q agreed with R on the value of an in-depth study and that it involved thinking. Doing the work in the field was also a positive factor. T rated the unit as an eight or nine. She considered that the laboratory provided something of use to the student and that snow is an inescapable material. These comments indicate meanings in the Immediate Area of Being.

N noted that going outside was preferred to remaining indoors. It allowed him to experience the activity and see for himself, and not rely on second hand information from the teacher. P was prepared to tolerate reasonably cold temperatures if field experiments appear to be of value. Both comments have meanings in the Immediate Area of Being. Because the topic of cold temperatures had been raised the students were then questioned regarding the weather conditions during the unit. All agreed that it had been exceptionally cold but that this made the conditions quite ideal for the type of activities they were doing, and actually enhanced their results. The cold had not really bothered them. This suggests meanings in the Immediate Area of Being. Three of the students indicated the development of a more positive attitude toward snow.

The students were asked for any concluding comments. R indicated that the unit was fine as is and it was a good one to do. S stated that the first semester class should have had the opportunity to do the unit. Apparently they were upset about not having had the chance. This suggests meaning in the Responsible Area of Being. T considered the laboratory to be of sufficient value that she also expressed concern for those who had not participated in it. This also suggests meanings in the Responsible Area of Being.

N noted that he and a friend intended to use a quin-zhee as an overnight shelter. According to N, people in this country have to deal with snow and the information gained could be useful. These meanings are in the Responsible Area of Being.

P stated that she had learned the material in Germany prior to coming to Canada four years earlier. Snow was a rare material but the theory of snow insulation was a school topic. This was a reason for not finding the unit of great value. N interjected that if she had lived her life in a country in which cold is a natural occurrence she would change her mind. P still considered snow to be a bother rather than a material of interest. Her meanings are in the Passive Area of Being.

R had discussed the unit at home with his father and with students from a first semester Biology 20 class who and had not done the unit. T also had discussed the unit with first term students who were curious. She explained what was going on and reported that they were quite interested. These meanings appear to be approaching the Responsible Area of Being. S indicated that information from the unit had been used outside the class. She had demonstrated the effects of a quin-zhee to her little sister who did not believe it was warmer under the snow. The sister was now able to understand how the quin-zhee could be used in an emergency. S sees an application of the unit to the benefit of others. This suggests meanings in the Responsible Area of Being.

Researcher's Observations on the Activities in Class 3

Observations

A full situational-interpretative evaluation must include actual observations of the students in a specific educational situation. Teaching the snow unit to my own Biology 20 class allowed me to observe the students in action and note their reactions as they proceeded through the various activities. I selected the five days from February 23 to March 5, 1982, inclusive, to conduct the unit. Because of semestering, Biology 20, a three credit course, was scheduled on alternate days with a period length of 80 minutes. Although this would interrupt the continuity of the outdoor activities to some extent, particularly over a weekend, it was the same situation being faced by other teachers in many school systems. The term had commenced on February 1, 1982, interrupted by the two days of Teachers' Convention. The students were only now becoming familiar both to me and to each other.

The materials were assembled and Part 1 of the student booklet was distributed to the students during the last ten minutes of their February 19 class. Biotic and abiotic factors had been discussed in class by that time and the unit was introduced as a special study on abiotic factors having a major effect on local organisms including man. The students were subsequently assigned to laboratory groups which were expected to continue through the laboratory activities during the remainder of the term. Students were grouped in pairs with the expectation that, during the snow shelter activities, the groups would be combined so that there would be sufficient manpower available to complete the exercise within the time limitations. Girls were paired with girls and boys with boys, based on my own bias gained from past experience this early in a semester. Because of uneven numbers one group was comprised of three boys. The students were then told to read the introductory section carefully and to begin Exercise 1, completing the snow sampler except for calibration, prior to the next class. They were also to read over all other parts of Exercise 1 and be prepared to set up their snow kits next period.

On February 23, 1982 the unit began. About thirty minutes were spent discussing abiotic factors in winter, using the student booklet as a guide. The class then broke up into their lab groups to complete Exercise 1. Nineteen of the twenty-three students had brought in snow samplers, including one of the two students who had been absent from the previous class. The majority had followed the lab instructions to the letter. Five students brought handles much too long and one had attached the handle lengthwise and backwards to the side of the tin can. Two students had used cans that were too large. These students indicated a lack of reading ability, interest or time in their preparations. The remaining materials required to complete the snow kits were available in class and the students completed their tasks within the remaining time.

During the final ten minutes of the period the students were instructed to read Exercise 2 carefully and informed that we would be going outdoors the next period to set up snow stations. The weather had been abnormally cold and windy. A good 30 cm of snow was on the ground. Conditions were ideal for clearly defined results to be obtained. From the reaction of the class however, there seemed to be a distinct reluctance to head for the outdoors. The students were warned to be prepared for outdoor work and for the extreme temperatures we could expect. The prediction of the snow temperature results for Exercise 2 were done on an individual basis at this time.

February 25 was cloudy and cold. The ambient air temperature outside the school registered -23°C. I had selected an isolated, treeless area which was easily accessible at one end of the school. Most of the students had come well prepared for the weather. Kits were gathered up and the students, with a minimum of reluctance, proceeded outdoors. There appeared to be an undercurrent of genuine enthusiasm, probably because outdoor or field work was a new experience for nearly all the students. Leaving the classroom and its routines seemed to be a motivating force.

Snow stations were quickly set up in locations I had mapped out on the blackboard. Steady winds had been blowing, forming a hard crust in some areas and dumping loose snow in others. Measurements were taken without much difficulty. The hard crust did interfere with thermometer insertions in the snow and two were broken. It was also obvious that three or four students had either not read the lab instructions as assigned or had forgotten the steps to be taken. One student would read the instructions out loud while his partner performed the task. The students had little trouble using the data sheets but did complain that it was hard to remember the precise instructions. A note was made to modify the data sheets to include either a prepared or student written outline of the specific steps required. This had already been suggested by the teacher of Class 1. Written work would tend to guarantee that the reading had actually been done.

The work was finished in about thirty minutes. They all appeared to have observed the temperature gradient in the snow and most were surprised at the specific temperatures recorded, even though some had predicted the correct sequence.

The final minutes of the class were spent pooling data for averages and picking up the first lab report forms, due for completion by the beginning of the next period. There was sufficient time for the students to begin their lab reports. Things seemed to have gone relatively well.

The second field activity was held on March 1 after a three day break including a weekend. Except for footwear the students were prepared for the weather, which remained unchanged. Three students had "forgotten" to complete their lab reports but the others had done a credible job. The first student entering class had commented that going out was a "drag" but there was no further evidence of a negative attitude.

After clarifying any problem points the groups moved out to their snow stations and completed recording their data. The air temperature was -17°C and the wind caused a definite chill factor. New snow had fallen and some of the snow stations had disappeared. Most were able to locate their sites but two groups were not certain. Station B sites were generally obliterated and students guessed where they were. Needless to say there were many suggestions about using flags as markers. In planning the unit this difficulty had been recognized but was weighed against the problem of the visibility of a marker to unwelcomed guests between classes. This had been a problem in piloting the unit and during other field activities. Albeit, marker of some kind would have to be used in the future.

The students worked hard and fast, talking and joking throughout and seeming to enjoy themselves. Again a few students either had not read or could not remember the instructions and had to use the booklet. The measurements at Station B proved to be a problem. Because of the open field environment, data that were to establish the concept of high density/low insulation simply were impossible to record. A note was made to either modify the exercise or change the site of Station B to a protected area. There was ample time for the students to get back to class, pool and discuss the data and commence the second lab report.

On March 3, 1982, the school day had been shortened for administrative reasons and class time reduced to sixty minutes. Part 2 of the instructional booklet was distributed to the students and the exercise on the snow shelter was examined in order to explain the need for a "piling of snow" session outdoors. Students had been instructed to bring snow shovels to class. Half had done so. More shovels were needed if the snow was to be piled up quickly. Fortunately the school had a shovel supply and enough were "borrowed" so that all students were suitably equipped. The groups were doubled for this activity (and the subsequent part of the exercise) and the snow piles were completed in less than a half-hour. Good-sized mounds were built although two groups would have preferred to keep theirs small for reasons of physical effort. Most mounds ended up larger than required, the students stating that bigger was better. The ample supply of snow made piling easy. Most of the snow was soft but the hard crust in some spots hindered progress. A tired but apparently happy crew returned to class. A total of six pre-quin-zhees had been made.

The remainder of the class time was spent by the students' reading the research article and completing the assignment associated with it. The loss of twenty minutes from the usual length of class period meant that for most students this assignment had to be completed at home.

March 5, 1982, was sunny but windy. The ambient temperature was -6°C as the students began to hollow out their quin-zhees. All but one group seemed to take pride in their construction efforts and quickly burrowed inside. The students had been asked to provide materials, such as plastic garbage bags, for doors. Some groups had forgotten and ended up using either a jacket or snow slabs, an interesting use of the natural materials at hand. One group continuously heard cracking as they burrowed out a hollow and at first thought the shelter would collapse. When nothing happened they regained confidence and completed the task. When they later had to break down the shelter for safety purposes they were shocked and impressed at its actual strength, along with others who also experienced some difficulty demolishing their quin-zhees. The required measurements made, each group member spent some time inside to record the impressions of the subnivean environment. The students mentioned the darkness, the silence, and in particular, the warmth. The impression of warmth was aided by the cold wind. Two or three groups decided to add extra people to the shelter and one of these groups recorded additional temperature data. With considerable reluctance the students broke down their shelters and returned to class. Final lab report forms were distributed but there was not enough time for the students to complete them in class.

On March 9, 1982, with the snow unit complete, the normal Biology 20 program resumed. Now back to usual routines, class enthusiasm and spirit which had appeared to develop during the field work seemed to wane. The students gave the impression that getting back to regular routines was a letdown. Many asked if more work of this type was going to be done. When the possibility of spring aquatic field work was mentioned, they appeared quite pleased.

Problems did crop up, particularly with the lab reports. More written and verbal instructions proved to be needed to indicate the depth expected of the discussion section. Most students did the minimum, some because they did not know how deeply to cover a topic, others because the minimum appeared to be a maximum for them. Some modifications in the data sheet are required to help students in remembering the measuring techniques required. Students who forget to bring a vital piece of equipment delay investigations and penalize others depending on them. A number of the activities must be adjusted to compensate for various environmental conditions. In general, however, the snow unit appeared to have been a reasonable success and, in my opinion, its basic objectives were met.

Reflections

In most theses the reflections and general comments on the results of the research are found in the final chapter. The research in this case has centered on the snow ecology unit and the many personal meanings that the participants attributed to this experience and to laboratory work in general. Considering that I had designed the laboratory unit and that the observations described above are those I have made on the activities within my own classroom, it seems an appropriate juncture to reflect on my own views of the unit.

My opinions on the effectiveness of laboratory investigations have already been described and mirror most of the feelings of the science educators cited in Chapter 2. However consciously and unconsciously my personal bias and vested interest in the success of the unit had also affected my interactions with the participants and the eventual written descriptions and interpretations. The snow unit was designed to give students a meaningful experience with the most obvious environmental factor in this country; cold and snow. That little prior use made of the winter environment for field investigations probably made the unit itself more effective than a tried but true, widely known experiment or series of experiments. This

Hawthorne effect may have influenced not only opinions of the unit but concomitant discussions on laboratory meanings in general.

More than four years were involved in the research, design and piloting of the unit. Initial user response had been positive and, with revisions, the basic goals of the unit were expected to be achieved. Students and teachers were not going to experience a situation which was, under normal environmental conditions, going to "bomb out". Nevertheless the temperament of the environment was a major factor in the success of the unit. Because of unusually mild winters a number of pilots had been abandoned. The air temperatures were typically winter but snow would be non-existant. Twice, an early thaw had raised air temperatures sufficiently to melt the snow only two weeks into the second semester. The unit could start but not finish. Even during the final evaluation there were problems with the weather. On the other hand, for Class 2 and Class 3, conditions for obtaining superior results could not have been more ideal. I must now consider whether the unit is one which can be part of a scheduled series of investigations in a semestered school year, or placed in some other science program where the teacher has the freedom to teach the unit whenever the conditions are favourable.

When conducting the unit in my own class there is little doubt that I was well prepared to introduce the unit, and may have done so with more careful attention to details and motivation than for other investigations. I had also subsumed information from the interactions with Class 1. The unit was going to run smoothly whether the students liked it or not. When things did not all go according to expectations, my reactions were more defensive than usual and any resultant remarks to the students probably reflected an additional touch of sarcasm. I did make every attempt, however, to approach this laboratory according to my usual presentation of lab investigations.

In general terms I was quite satisfied with the results of the snow ecology unit. The students appeared to be enthusiastic and the concepts involved had been clearly illustrated. An exception was the density experiment which was, effectively, a dismal failure. Students could not locate previously marked measuring stations and, through my on-site questionings, demonstrated that they had not seen the significance of density at all. It exemplified frustration in both the students and myself. Students were frustrated when thermometers broke in the snow, when snow crystals were difficult to classify with the magnifying glasses they were given and when a few of the snow samplers broke. I was not overly receptive to students who could not follow my "simple written instruction", who broke equipment, who had obviously not read instructions beforehand, and who looked disinterested. The failure of many students to bring shovels and door materials for the final activity was irritating, to say the least. This might have ruined the experience for both students and myself if an alternate source had not been available in the school. On the other hand, I was impressed with the students who had forgotten to bring doors for the quin-zhee but imaginatively used slabs of hard-packed snow as an alternative. The effect was not only more realistic but suggested that they were sufficiently interested in their work to stubbornly complete it rather than give up. This technique will now become part of the snow unit instructions.

The enthusiasm of the students for the work, their positive attitude in most cases, even while working outdoors in the intense cold, and their amazement at the data, individual and pooled, was most rewarding. They not only could discuss and extrapolate from the concepts illustrated but even discussed having used the information out of class and school. The experience of interviewing, discussing the "pros" and "cons" of the snow unit and lab work in general, revealed to me that the laboratory enterprise, according to my interpretation of their descriptions, had more effect in terms of their personal experience than I had realized.

Summary of Student and Teacher Interpretations, Class 3

This summary includes items which provide alternative or additional interpretations from those described in the previous two summaries. Teacher comments are those of the researcher since both he and his students were the participants in this situation.

Passive Area of Being

Student frustration was a key factor in reducing the laboratory to an "I'll do it because I have to" situation. When one of their snow stations was obliterated because of a storm there was an observed lack of enthusiasm to continue with that part of the exercise. This was mentioned by the students during interviewing. Their inability to adequately classify snow crystals, due to techniques and equipment, resulted in the students' "doctoring" of results. They also mentioned that in a laboratory situation where they thought the teacher was less than enthusiastic about an activity, the lab was merely considered to be "busy work".

As previously noted in both Class 1 and Class 2 interviews, reading appears to be of some concern. From observing and working with the students in the lab situation, the researcher suspected that many individuals had done little preparation requiring reading prior to the activities. The students during the interviews confirmed that reading was not enjoyed and for some only done with reluctance.

Immediate Area of Being

An aim of the researcher was to design activities in which the data collected was reasonably clear and the implications obvious. The students noted that they did need things to "go right" to maintain interest.

In discussing data collection we agreed that predesigned data recording sheets were required to help in the organization of data, particularly in the intense cold experienced during the unit.

The researcher had included a number of diagrams to supplement instructions in the lab booklets. The students stated that illustrations help to clarify a number of points of which they were unsure. They also mentioned that labs incorporating the use of previously learned techniques were valued in that time was saved and data collected was more accurate. Practice makes perfect. From experience the researcher had observed this desire and thus it was deliberately incorporated into the unit. The students did suggest that when new or unusual equipment was to be used, a prior teacher demonstration was valued.

Responsible Area of Being

The students indicated that another aspect of using previously learned techniques was to improve their ability to discuss the data, draw better conclusions and thus raise their level of understanding.

It was agreed that some lab work took up a lot of time to make a point in comparison to students' being told specific facts. One student thought that if a course load was heavy, the class could be penalized by doing too much lab work, implying that a lab activity must be seen as having definite value, otherwise it restricts other modes of learning which are of value. All agreed however that the lab provided a learning experience which regular classroom and textbook learning could not equal.

CHAPTER 7

A SUMMARY AND RECOMMENDATIONS

Summary

The meanings teachers and students give to the snow ecology unit and to laboratory activities have been evaluated qualitatively using a situational interpretative approach. As such, it is useful in revealing one aspect of both the snow unit and the role of the laboratory in high school biological science in examining the effectiveness of laboratory oriented exercises as a teaching strategy. Although no final conclusions should be made based on the approach taken in this investigation, both students and teachers, through interviews and their analysis, have suggested that the snow ecology unit and the laboratory enterprise it exemplifies are indeed worthy endeavours.

The laboratory exercise, typical of the high school setting, places restrictions on what a student may or may not do and thus may or may not learn. This implies that experiences in the laboratory would tend to have meaning in the Passive and Immediate Areas of Being. However, with open-endedness, the applications to other studies and the real world, plus a positive attitude on the part of the instructor, students may develop meaning in the Responsible Area of Being, a characteristic for which educators must continually strive. In developing a program, the educator should attempt to design curricula which will permit this to happen. It is too easy to emphasize content and rote memory because it is simple to grade this type of learning. It is also difficult to conceive of a teacher, having attitudes toward laboratory work with meanings in the Passive Area of Being, promoting otherwise in students.

The mark or grade, the educator's ultimate source of power and control, is still the most direct method of measuring students' apparent success in mastering knowledge. As a motivating force it often must restrict both students' and teachers' meaning of an activity to the Passive Area of Being, but few will suggest it is not a necessary tool in educational repertoire of evaluation approaches. Meaningful human experience as a major goal of any educational endeavour must permeate the thinking of our program developers.

The willingness of both teachers and students to respond to the situational-interpretative approach, specifically through the interview, is clearly evident from their comments about the snow unit and laboratory activities. These may serve in part as a guideline for anyone intending to use the laboratory as a teaching strategy in the biological or other sciences.

Few students felt that the laboratory or its associated activites had meanings within the Passive Area of Being. Meanings in this area were characterized by comments indicating that labs in general had to be completed in order to complete the course or to gain a passing grade. This also involved the reluctance to read instructions or paragraphs of information unless a penalty of some nature were imposed. A few labs, particularly dissections, were simply disliked and completed only because they were required, regardless of their apparent value. Labs which simply verify clearly understood concepts also fit into this category, the attitude being, "Why do something we already know?" Boredom is implied.

A number of meanings bordered on the Passive and Immediate Areas of Being, depending on a specific interpretation at a specific time. The lab is definitely considered a break from usual (and often boring) classroom routines. To many, the lack of clear cut results (data) and the malfunction of equipment may relegate activites from the Immediate to the Passive Area of Being, the lab then being considered a worthless, time wasting experience. This was exemplified by the problems encountered by the students when attempting to age the snow crystals, which led, in some cases, to the recording of data simply in order to have data. A poor working environment may also negate, to some extent, a potentially important lab assignment. However, if interest is aroused, the effects of unusual conditions such as the intense cold experienced by the participants in the snow ecology unit, may be minimized.

In the example cited above, recognition on the part of students that the cold reflected the realities of a

Canadian winter indicated meaning in the Immediate Area of Being. This area was also exemplified by such comments as "It was fun" or "I was able to talk to other students". Factors which aid students in obtaining, handling and interpreting data can also have meaning in the Immediate Area of Being. Students suggested, that to be effective, labs must provide the participant with clearly stated procedures, suggestions on handling data collection and a way of presenting data interpretations in a logical manner. If procedures already learned in a previous lab could be used in a subsequent investigation, it appeared to be a more meaningful learning experience. There must be sufficient time allotted for an activity to be completed and the data examined with care. Too much material presented at one time leads to confusion and frustration. Diagrams, such as those used in illustrating temperature recording points, are valuable as additions to verbal explanations. Making predictions prior to data collection arouses interest and the comparison of predicted and actual results tend to reinforce the concept under study. Definitive, as well as surprising data, which allows for straightforward conclusions, also reduces the frustrations of handling limited amounts of inconclusive information. The results must correlate with the clearly stated purpose of the investigation.

Students generally felt that a report of their activity was necessary. They suggested that this requirement plus its evaluation were measures of their personal understandings of the concepts studied and added incentives to do a more thorough job of both the investigation and the report. It is interesting to note that the "incentive" concept is also a major factor in the "free enterprise" philosophy of our western tradition.

The students felt that lab work was a valuable activity. They seemed to understand concepts more clearly, remember them longer and have less difficulty in recalling the information learned, compared to normal classroom and textbook learning. By working in groups, information could be shared and problems discussed.

Many meanings were clearly within the Responsible Area of Being. The lab provided a more personal control over their learning experience. They were able to make first-hand observations and actually experience scientific phenomena. Seeing is believing. As a result they could make a decision on the validity of a test or concept rather than accept the written (text) or spoken (teacher) word as the authority. Many were prepared to suggest and investigate additional topics arising from the basic activities. They not only desired to produce a laboratory report but suggested that a proportion of the questions involved in the inerpretation of data be at a difficult level. This would challenge them to integrate theory with practical investigations, thus making the lab more meaningful. Since biology deals with life, some students considered that field work allowed them to examine events which were in a more realistic situation. Students appeared to value highly activities and concepts in laboratory work which can be applied to everyday life. The quin-zhee investigation is representative. Not only could the students see its potential use in an emergency situation, but some actually discussed this aspect out of school, even to the extent of constructing them at home to prove their point.

The general conclusion of the students was that laboratory work must be an integral part of any biology or science program, and through the concepts examined, such as those in the snow ecology unit, could be learned from text book or classroom information, the overall significance of these concepts would be severely reduced and the course limited to an exercise in the memorization of facts.

The teachers interviewed also expressed ideas and concerns both for the snow ecology unit and laboratory work in general. Many of their observations were similar to those of the students and within the same Areas of Being. These include the fun aspect, breaking with classroom routines, being out in the real world and the like. They did have a number of additional comments which reflect their role as teacher participants.

Both teachers noted that students will often tend to take the easy way out of an assignment or exercise and produce the minimum unless closely supervised. They see the students as having meanings in the Passive Area of Being, while their own meanings are in the Immediate Area of Being. The latter "area" is exemplified by further comments.

Both teachers found the snow ecology unit to be well organized, required minimum teacher background and preparation and easily modified if necessary. They saw the students as having little difficulty in performing the activities, establishing concepts and understanding the principles illustrated by the data they gathered. Questions in the lab report require both simple and complex answers, although both would like to see an increase in higher level questions.

Jones likes to be personally involved in the lab and this may be reflected by students' comments on the positive attitude displayed by teachers doing lab work. Smith sees the lab as a chance for students to assume all responsibility for the activities, and thus he observes rather than participates. He also feels that some lab work is not essential and that the techniques can be taught within the classroom environment.

Both teachers indicated that the evaluation of lab work should indicate a bias toward higher level discussions of concepts and issues raised in the lab. Smith finds that students who either cannot or will not work at these levels find the lab experience somewhat frustrating. This indicates meanings in the Immediate Area of Being.

A number of their comments indicate meanings in the Responsible Area of Being. Jones and Smith saw the laboratory experience as essential for a complete education in the sciences: discovery initiates excitement and interest; it is "doing" science. Smith added that reading research articles is also one of the roles of a scientist.

Jones is concerned about the safety of the student in different laboratory situations and takes it into consideration when doing an activity, a topic not raised during student discussions. She still feels that even with a risk factor, the laboratory is the place to be for practical experience.

Both teachers use the lab as an activity to be modified to suit personal and specific class needs and recognized their own need for a good background in the subject area to perform to their ability. Sufficient time for an activity is valued since it permits the student to move through each step without rushing thus contributing to a better quality of work.

Jones and Smith both raised concerns with the ability of students to read and communicate in written form. The lazy student does little of either and good students require extra motivation, particularly marks, to make them fully concern themselves with reading and written skills. The teachers indicated that these skills are essential and can be developed through laboratory work.

In conclusion, Jones and Smith noted that a major feature of the unit was the relevancy of the material. It not only fit in with the theme of Biology 20 but dealt with the local, real Canadian environment, which had more meaning for the student both from the theoretical and practical points of view. Where possible, laboratory activites should capitalize on this factor.

It was indicated in Chapter 2 that many science educators consider laboratory activities to appear to provide students with more than simply a learning experience, even when data from quantitative studies were unable to substantiate this contention. The meanings that students gave to the winter ecology activities lend considerable support to these "gut" reactions. A situational type of investigation would seem to be a method by which many hidden meanings can be revealed.

In terms of the value of laboratory experience this study indicates that students can and do move through the Areas of Being. Though the initial stage of an activity is often in the Passive Area, once the laboratory begins, meanings regularly tend to shift into those characteristic of the Immediate Area and, in many instances, end in the Responsible Area of Being. I view this as a highly desirable effect of any learning experience. In this respect the science laboratory has considerable merit and it is imperative, therefore, to encourage the use of laboratory experiences whenever and wherever possible. The use of more open-ended investigations rather than the structured format as used in the winter ecology unit may accelerate this effect. Indeed, it may be that all the participants may move toward the Transcendent Area of Being.

Because the teacher is still the centre of focus in the majority of classrooms teacher attitudes towards laboratory activities may modify the students' attitudes. Regardless of the teacher, some individuals may proceed through an investigation with reasonable success and indicate meanings in the Immediate and even Responsible Areas of Being. If, however, they suspect that the teacher considers a particular activity, or lab work in general, as being less than desirable, they assume the same attitude. The students of those teachers tend to have meanings which are mainly within the Passive Area of Being or, at best, extend into the Immediate Area. The value of the experience from the viewpoint of the student has been severely reduced. Science teachers, of necessity, must be convinced of the positive values of the laboratory if a truly successful science program is to result.

Comments On The Research Methodology

From my experience with qualitative investigation, a number of comments seem appropriate and of value to those considering the use of this particular methodology.

Qualitative methods do provide important data in terms of student and teacher meanings of education situations.

As such they are to be encouraged, where suitable, in science education research.

Interviewing participants leads initially to a stressful situation. Nervousness on the part of an interviewer may result not only in poorly formulated questions but restricted responses on the part of the interviewees. Researchers preparing themselves for emic-evaluation approaches should carefully study interview strategies and practice interviewing techniques.

The number of prepared guide questions for the interviews should be kept limited and as general as possible. Too many questions may tend to restrict or even predetermine the final data obtained. Examination of the information collected following the completion of interviews will, in all probability, reveal a number of themes which can then be used to organize the data for more meaningful interpretation.

Group sizes involved in interviewing will, of necessity, vary in size depending on many factors. However, I have found that a group of three appeared to be the most satisfactory size. Within the ever-present time constraints, interviewees are able to interact with the interviewer and each other, yet still appear to have the "security" of a group situation. The preparation of subsequent interview transcripts is also made more manageable.

The time involved in qualitative research is considerable. A researcher must recognize that time will place constraints on the length and depth of the study and the number of participants involved. It is recommended that a major block of uncommitted time be made available, particularly during the data-collection and verification phases of the research.

The bulk of research time involves the preparation of transcripts from taped interviews. This may be reduced if the interviewer, rather than preparing word-for-word transcripts, summarizes the points made in the conversations and adds interpretations where relevant. A permanent set of tapes must, however, be available if specific references or quotations are required. Validation of comments made by the participants is critical. The participants in this study were given summaries of their comments, were quick to point out any misinterpretation of meanings on the part of the researcher and appreciated the opportunity to clarify them.

It is quite difficult for any interviewer to continuously jot down conversation sequences and comments, yet still appear to be interested in what an interviewee is discussing. Serious consideration should therefore be given to the use of videotape recorders during interviews. Body language, such as the nodding of a head, a shrug, a smile or other subtle actions may reveal meanings unavailable with only audiotaping. As well, in a group interview, possible difficulties in determining exactly who is speaking and the precise sequence of utterances can be resolved.

To maximize the effectiveness of educational research, investigations should consider using both quantitative and qualitative methods within the same study. Alternatively, a team approach to a research topic in which different members use different approaches could provide more meaningful information on the worth of curricula.

In order to gain general acceptance within the scientific community, scientific hypotheses and theories require strong supporting evidence. This should equally apply to science education, regardless of its classification as a social science. The methodology used in the gathering of meaningful data must, however, reflect the social aspect of the investigation. To rely wholly on a single research paradigm is to ignore the information that alternative strategies, if available, must surely provide. Mary Lee Smith (1982) made the following comment, one I feel is most appropriate, on naturalistic (qualitative) methods in research in science education:

> In order to be more authentically scientific one needs disciplined collection of evidence using a variety of methods, dispassionate and logical interpretation of the evidence, examination of the assumptions underlying both evidence and the methods that generated it, evaluation of the perspectives of individuals who provide the data. Naturalistic methods can make research in science education more scientific.

If quantitative and qualitative studies are used to complement each other where possible, the resultant data must surely provide us with more meaningful information than any one single research paradigm is capable of doing.

This study has provided some support for the inclusion of laboratory experiences as an integral part of biology and other science programs at the high school level. However, typical of most research investigations, probably more questions have been raised than answered. Future attempts to answer these questions should provide evidence allowing us to make more definitive statements as to the worth of laboratory activities.

Personal Reflections

Curricula are always undergoing formative evluation, if not by the designer, certainly by the practicing educator, in order to meet the needs of students, school and community. The snow ecology unit is no exception. As discussed in Chapter 4, the module underwent many modifications before entering its final test as part of an in-school program. Both teachers and students, by their participation in the study, were able to provide support for most of the activities as well as constructive criticism for future changes. These suggestions for change are welcomed and will be acted upon prior to further use.

The qualitative research method used during this study appears to have considerable value as part of a holistic evaluation approach to a curriculum by revealing the user's point of view. The users, teachers and students, must have direct input into a curriculum study since they, not usually the designer, are in the front lines facing the day-to-day realities of classroom, school and community.

Wilson and Rothe made the following comments with regard to their research in qualitative evaluation:

> I view the study of emic-evaluation inquiry as being a product of my thinking. Dialectically, I have also become a product of my work. Such a dialectic relationship between self and the social world acknowledges experimental knowledge as a foundation for educational research (Wilson 1976).
>
> Within the parameters of dialectic time and change we need to be attentive to a basic existential phenomenological assumption that each occurrence in time, as described, represents one description of one activity at one time. If I were to undertake a similar research in the future the procedures would common-sensically change since participants, situations and time will have changed (Rothe 1979).

My own views on the snow ecology unit and the laboratory component of a biology program must of necessity reflect the views of the participants. I could not help but be involved with each of the ongoing situations, evident by examination of the interview records. The approach, style and questioning techniques were modified during the investigations, reflecting past problems and changing when the situation appeared to merit change. This is an illustration of the living social relationships in the classroom and the world.

Because the participants in science activities are individuals, they have their own interpretations and meanings of laboratory experiences. While some may relish the idea of a scientific investigation others, for whatever reasons, have little or no interest in the sciences. Within a class one invariably finds a wide spectrum of abilities, interest and personalities. To expect all students to think of laboratory experiences in terms of the highest Areas of Being is to be somewhat unrealistic. Nevertheless, if the results of this study have any significance it is to suggest that the laboratory enterprise is a definite and significant part of a biology program and that there are many factors to consider when designing a suitable laboratory experience for most of those who participate.

In conclusion, the students and teachers, by participating in this study and willingly expressing their thoughts and feelings, were themselves acting in the Responsible Area of Being. The snow ecology unit and the laboratory experience it represents, within the limits of this study, appeared to exhibit those characteristics held to be valuable by its participants.

Table 1

Lowest January Temperatures, Average Date of Freezing and Total Snowfall for Some Selected Locations in Canada, Adapted from the Canada Year Book 1970-71

Location	Lowest Jan. Temps. on Record °C	Average date of freezing First in Autumn	 Last in Spring	Total Snowfall in cm.
Kamloops, B.C.	-35.6	Sept. 26	May 4	82.6
Edmonton, Alta.	-49.4	Sept. 19	May 27	136.7
Saskatoon, Sask.	-48.3	Sept. 7	May 27	109.7
Winnipeg, Man.	-47.8	Sept. 19	May 26	130.3
Thunder Bay, Ont.	-41.1	Sept. 8	June 1	214.9
Toronto, Ont.	-32.8	Oct. 4	May 9	139.4
Ottawa, Ont.	-38.9	Sept. 28	May 13	218.7
Montreal, Que.	-33.9	Oct. 21	April 24	250.4
Quebec City, Que.	-36.7	Oct. 11	May 7	304.3
Moncton, N.B.	-37.8	Sept. 23	May 24	275.8
Halifax, N.S.	-29.4	Oct. 28	May 1	180.1
St. John's Nfld.	-29.4	Oct. 9	June 1	380.2

Table 2

Some Common Snow Terms Adapted from Pruitt (1975) and Phillips and Watson (1977)

English	Inuit
Snow (falling)	Anniu (an-nee-you)
Snow that collects on trees	Qali (kall-ee)
Snow on the ground	Api (aye-pee)
Depth hoar (heavy frost at ground level	Pukak (pew-cak)
Wind-beaten snow	Upsik (up-sik)
Smokey snow or drifting snow	Siqoq (see-cok)
Sun crust	Siqoqtoaq (see-cok-tow-ak)
Drift	Kimoaqruk (kee-mow-ak-rook)
Sharply etched wind-eroded snow surface	Kaioglaq (kay-oh-glak)
Bowl-shaped depression in snow around base of trees	Qamaniq (com-an-nique)

Table 3

The Texts Presently Authorized for the Biology 20 Program in Alberta

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Biological Sciences Curriculum Study. 1973 Biological Science: An Ecological Approach. BSCS Green Version, third edition. Agincourt: Gage and Co.

Biological Sciences Curriculum Study. 1968 Biological Science: An Inquiry Into Life. BSCS Yellow Version, second edition.
Don Mills: Longman Canada. The Laboratory manual of this program is also to be used with Otto and Towle.

Otto, J. H. and A. Towle. 1973 Modern Biology. Toronto: Holt, Rinehart and Winston.

Table 4

The Titles of the Snow Ecology Projects Designed for Biology 20 Students

Title	Core or optional
Snow as an insulating material	Core
The snow shelter and the subnivean environment	Core
The winter diet of the snowshoe hare	Optional
The aquatic environment in winter	Optional
A census of animals activity in winter	Optional
Insect activity in winter	Optional

Figure 1. Three Major Perspectives for Interpreting Programs Based on Werner (1978)

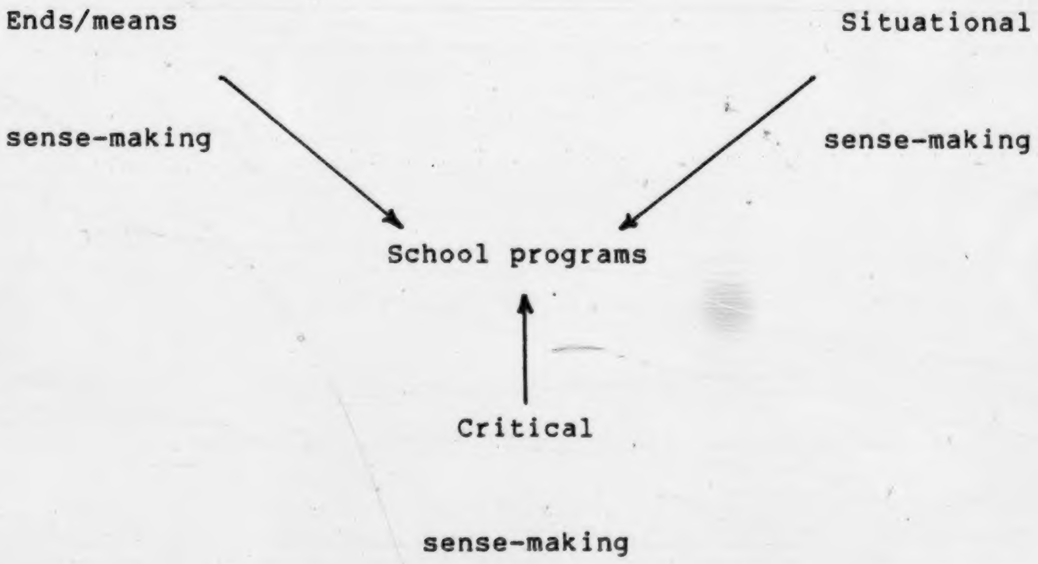
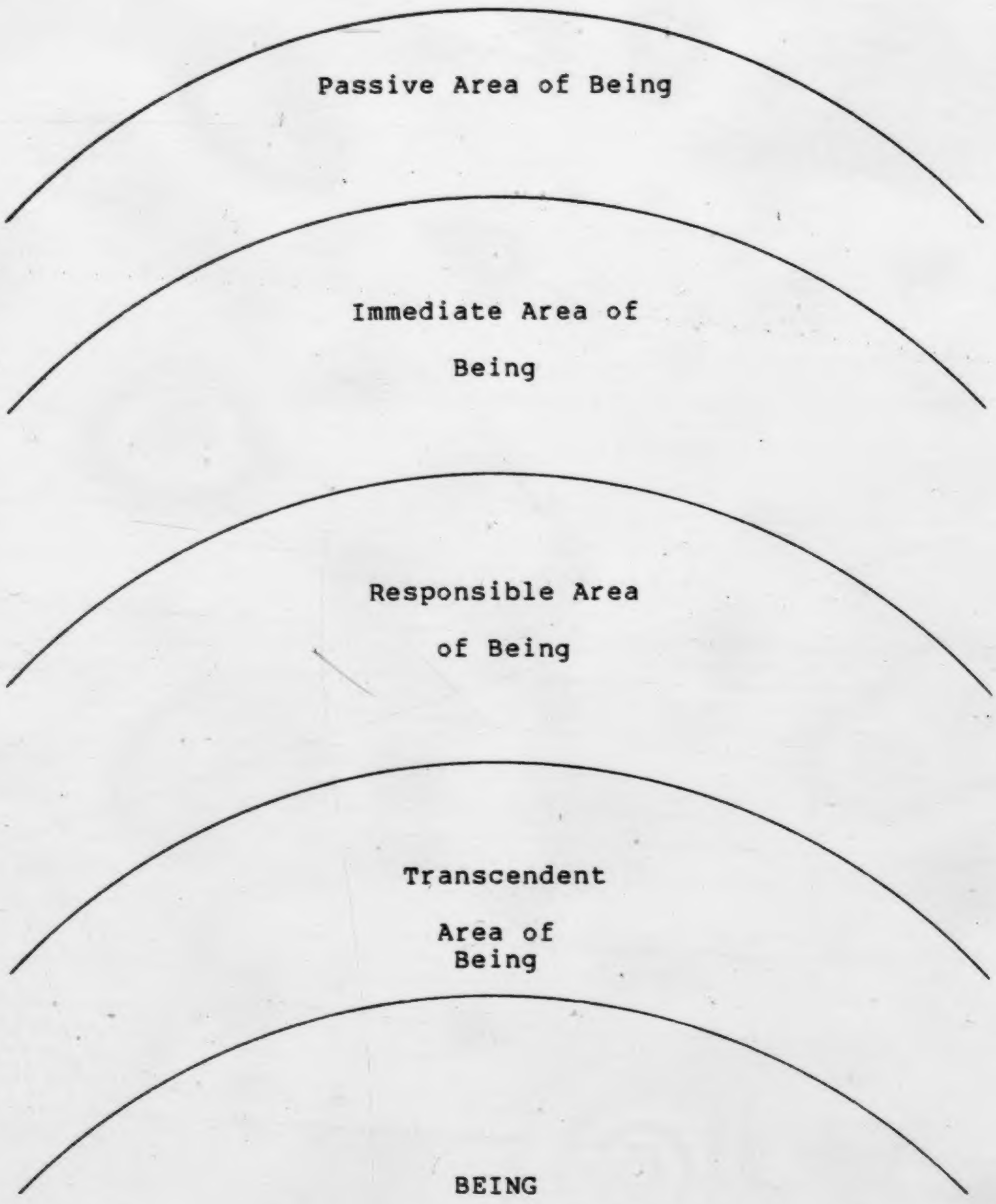


Figure 2. The Four Areas of Being (Rothe 1979)



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APPENDIX A

THE SNOW ECOLOGY UNIT STUDENT INSTRUCTIONS PACKAGE

WINTER ECOLOGY ACTIVITIES
FOR USE IN
SECONDARY SCHOOL SCIENCE

PART I

Snow cover, for many species, is the most important element of environmental resistance and struggle against this particular element is almost beyond the species' ability.

A. N. Formozov (1946)

In the literature of the sciences that ought to be most concerned there is even yet little to suggest that snow is a major element in the environment of life.

W. O. Pruitt, Jr. (1970)

INTRODUCTION

Like it or not, low temperatures and snow are with us during much of the year and, in most of Canada, winter is the dominant season. You are about to engage in an investigation of our most common "mineral", snow, and its impact on the organisms that live totally or partially in our sub-arctic climate. You may be in for a few surprises or simply verify what you already know or suspected. Regardless, an examination of the winter environment should illustrate the problems facing organisms, human or otherwise, which live in a northern (boreal) country and some of the adaptations which aid in their survival.

All organisms, man included, are totally dependent on their environment for survival. The environment, the total surroundings of an organism, may be divided into two parts for convenience. Thus, the biotic environment is everything in a recently alive (human, bears, mosquitoes, bacteria etc.) while the abiotic environment consists of all those non-living factors which influence an organism's existance (light, sound, climate, minerals, etc.).

Any change in the environment will have an impact on organisms. If they adapt to the change they survive. If not, extinction is a distinct possibility.

In Canada, as in all northern countries, the most critical abiotic factor is climate, particularly the extremes of temperature. In winter this is always accompanied by that unique "mineral" known as snow. The lives of the earliest inhabitants of Canada, the northern Indians and the Inuit (Eskimo), were so influenced by the presence of snow that they developed a complete vocabulary of snow terms to help them describe specific conditions which could affect such activities as hunting and travel. These terms are so precise that many have been added to the language of science. Table 1 gives some of the commonly used terms. A number will appear in the investigation to follow.

Table 1. Some Common Snow Terms Adapted from Pruitt (1975) and Phillips and Watson (1977).

English	Inuit
Snow (falling)	Anniu (an-nee-you)
Snow that collects on trees	Qali (kall-ee)
Snow on the ground	Api (aye-pee)
Depth hoar (heavy frost at ground level	Pukak (pew-cak)
Wind-beaten snow	Upsik (up-sik)
Smokey snow or drifting snow	Siqoq (see-cok)
Sun crust	Siqoqtoaq (see-cok-tow-ak)
Drift	Kimoaqruk (kee-mow-ak-rook)
Sharply etched wind-eroded snow surface	Kaioglaq (kay-oh-glak)
Bowl-shaped depression in snow around base of trees	Qamaniq (com-an-nique)

Organisms that are full time members of our country must adjust to temperatures ranging anywhere from 35°C in summer to -50°C in winter. Occasional extremes extend each end of the scale. Table 2 provides some interesting data on low temperatures and snowfall from some well know locations across Canada.

Table 2. Lowest January Temperatures, Average Date of Freezing and Total Snowfall for Some Selected Locations in Canada, Adapted from the Canada Year Book 1970-71

Location	Lowest Jan. Temps. on Record °C	Average date of freezing First in Autumn	 Last in Spring	Total Snowfall in cm.
Kamloops, B.C.	-35.6	Sept. 26	May 4	82.6
Edmonton, Alta.	-49.4	Sept. 19	May 27	136.7
Saskatoon, Sask.	-48.3	Sept. 7	May 27	109.7
Winnipeg, Man.	-47.8	Sept. 19	May 26	130.3
Thunder Bay,Ont.	-41.1	Sept. 8	June 1	214.9
Toronto, Ont.	-32.8	Oct. 4	May 9	139.4
Ottawa, Ont.	-38.9	Sept. 28	May 13	218.7
Montreal, Que.	-33.9	Oct. 21	April 24	250.4
Quebec City,Que.	-36.7	Oct. 11	May 7	304.3
Moncton, N.B.	-37.8	Sept. 23	May 24	275.8
Halifax, N.S.	-29.4	Oct. 28	May 1	180.1
St. John's Nfld.	-29.4	Oct. 9	June 1	380.2

Wind is an additional problem since it results in a chill factor which reduces the effective temperature even further.

When low temperatures arrive in winter, the activity of organisms is affected and the availability of food is limited, especially when covered by snow. A.N. Formozov (1946), a Russian biologist and one of the first to study the impact of winter on organisms, has provided biologists with a method of grouping our northern animals on the basis of their ability to withstand winter. His three major groups are defined:

1. Chionophobes - animals which are unable to adjust to snow and must avoid it or die; snow haters (eg. pronghorns; summer birds; waterfowl); from chion (Greek for snow) and phobos (Greek for fear).
2. Chioneuphores - animals which can survive in regions of snow (eg. moose; elk; fox).
3. Chionophiles - animals which possess adaptations for snow and whose range is limited to regions of the world that have snow during the winter season (eg. snowshoe hare; caribou); snow lovers.

Plants are also affected by snow and cold temperatures. Ice or snow that builds up on branches of trees and shrubs (qali),a condition best observed on fir and spruce trees, may cause them to bend or even break. Plant life on the ground may be covered by snow or, if wind swept, exposed to both the low temperatures of winter and the wind chill factor. In extreme cold, water in the cells of shrubs and trees may expand enough to split the plant from top to bottom. Since plants are the base of food chains and webs, their survival is critical for all other organisms.

Biologists now refer to any climatic effect on an organism as bioclimate. Therefore in order to understand the impact of temperature and snow on organisms one must study the winter bioclimate and this necessitates the collection of all types of data. The first step is to examine snow itself.

SNOW AS AN ABIOTIC FACTOR

In order to obtain data on snow/temperature relationships, it is necessary to establish a snow station.

A snow station is a location, often permanent, where a number of measurements are recorded concerning snow and temperatures. These may include the temperature above, within and beneath the snow cover, snow depth, snow density, the number of snow layers, and often snow hardness and crystal structure. The data recorded offer clues as to the environmental effects of this unique substance.

Sometimes a permanent station is set up during the autumn before the first snowfall. Various instruments, many of them complicated and expensive, are installed and data can be accumulated over long periods of time.

More often, temporary stations are established at convenient sites any time of the winter. Very little equipment is required and reasonably accurate observations can be made.

In the following paragraphs some of the basic measurements taken at a snow station are described, along with brief comments on the usefulness of the data collected. The Inuit terms for special types of snow are now part of biological language and should be learned as you proceed.

Snow Depth

The deeper the snow (api) the greater its weight on anything beneath it and, for some organisms, the more difficult it is to move through or shovel the build up of snow. Light is prevented from reaching the ground, many sources of food are covered, and as a result, organisms must adjust their feeding habits or leave the area completely.

Snow on branches of trees (gali) can bend or even break them off. The depth of snow in a specific environment can provide information on the survival factors for native organisms.

Snow Strara (Layers)

Unless blown away, melted snow accumulates over time with each snowfall overlying earlier ones. Because each snowfall has its own particular characteristics, a crossection of the snow shows each individual fall as a layer or stratum, much like the appearance of sedimentary rock layers. Crystals of snow can be sampled and even given an age based on structure.

Snow Density

Snow can range from soft powder to near ice. Ask any skier! Density indicates how close the snow crystals are to each other or, in layman's terms, how packed the snow is. Light snow can have a density of 0.2 g/cm^3, while the density of ice is about 0.9 g/cm^3. Snow is always compared to water, which has a density of 1.0 g/cm^3. If you had a choice of being hit by a snowball of density 0.3 g/cm^3 compared to one of 0.8 g/cm^3, which one would you choose? Dense snow, covering food for an animal, can prevent feeding; dense snow, on the roof of a house can cause collapse. Engineers must take this into consideration when designing buildings.

Temperatures

Snow and low temperatures go hand in hand and have a pronounced effect on organisms that live in snowy regions. Since organisms are in physical contact with snow and air, the temperatures of both play a critical role in the survival ability of organisms.

Snow Crystal Structure

Snow crystals change with age and with climatic factors. The examination of crystals can reveal the age of the snow and whether it has been wind blown, melted and refrozen, etc. This technique is used, in part, to determine the age of glaciers.

Pukak Development

When snow has been on the ground for a while, a gap, filled with large snow crystals (pukak), normally forms where the snow contacts the soil or grass. For organisms under the snow, the pukak layer is very significant.

To summarize, information from the above measurements (plus others) gives a picture of the conditions northern organisms face at different times of the winter and indicates the probable survival rate of many species, including man. For example, avalanche prediction in the mountains is dependent on knowing the angle of the slope, snow depth, density, crystal structure, number of strata and age. A combination of these factors eventually reaches a critical stage where even a loud shout will cause tonnes of snow to cascade downhill, demolishing everything in its path.

The purpose of the activities which follow are to give you experience in collecting data from a snow station, interpreting the data and predicting some of the effects of winter on northern organisms.

Exercise 1. The Preparation of Snow Measuring Kit

A snow kit, consisting of basic measuring tools, should be assembled before going into the field. Because the kit must be portable, bulky materials have to be kept to a minimum. Keep this in mind when collecting your equipment. Some items will be provided by your instructor; others you will have to obtain yourself or construct. Instructions for making equipment are given after the following list of items basic to a snow kit:

Thermometer - alcohol type; the thermometer must be reinforced to prevent breakage when inserting into hard snow (eg. tape the thermometer to a wooden ruler, dowling or the equivalent).

Snow Sampler - used for the determination of snow density.

Spring Balance - (or equivalent) - used for determining the weight of a snow sample; it should be as sensitive as possible (eg. 0-250 g range).

Metric Ruler - a metre stick or roll type tape is preferable.

Brush (Paint) - any brush 5 - 8 cm wide with soft bristles is adequate; used to prepare the face of a snow profile.

Hand Lens - any magnifying glass will do; for examination of snow crystals.

Pencils; Erasers - for data recording and correcting.

Snow Crystal Classification Charts - one chart should be used for classifying new snow; the other for the crystal structure (thus the age) of the snow.

Disposable Aluminum Pie Plate - for use in constructing balance pan.

Select a container that is portable and holds all the above materials.

Some examples are:

- a cardboard box with a handle
- a small backpack
- an unused microscope carrying case (Watson & Phillips 1976)
- plastic ice cream bucket

Plans for making and using some of the bove apparatus follow below.

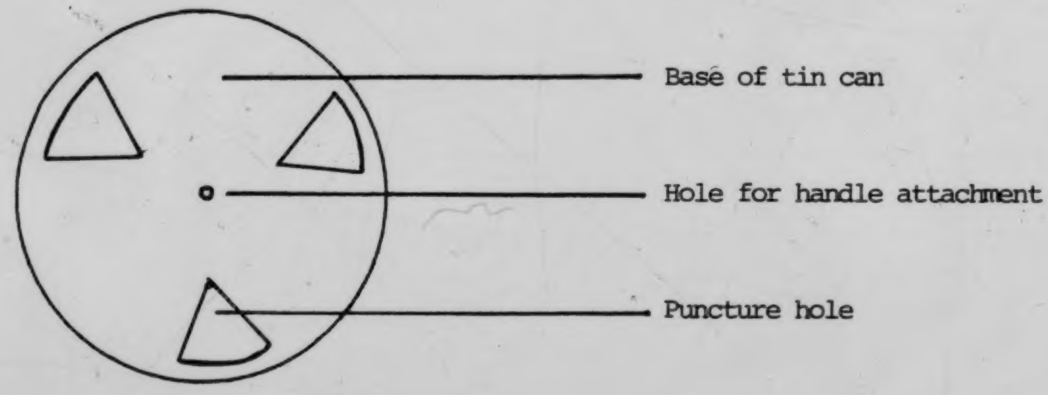
The Construction of a Snow Sampler

Materials - tin can 300 mL or larger.
- juice can hole puncher.
- piece of dowl or equivalent (eg. hockey stick handle) about 12 cm long.
- graduated cylinder (or equivalent).
- wood screw and a screw driver.

1. Obtain a clean tin can with the top removed.

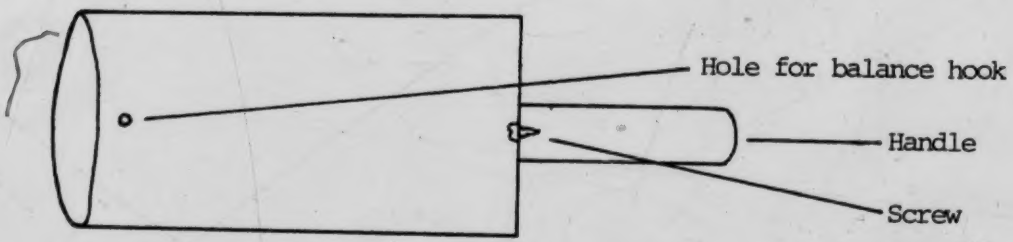
2. Using a graduated cylinder fill the can to the top with water in order to determine its volume. Empty and dry the can and record the volume on the side (waterproof felt marker is excellent).
3. Using the juice can hold puncher, make three holes in the base of the can (Figure 1). Carefully flatten the projecting pieces of the tin flush against the base of the can.

Figure 1. Hole Locations in the Base of a Tin Can Snow Sampler.



4. Puncture a hole in the centre of the base and attach the handle using a wood screw (Figure 2). Drilling a small hole in the end of the wooden handle makes the job easier.

Figure 2. Side View of a Tin Can Snow Sampler with the Handle Attached.



5. Drill or puncture a small hole near the top of the can which is large enough for the hook of a spring balance to enter.

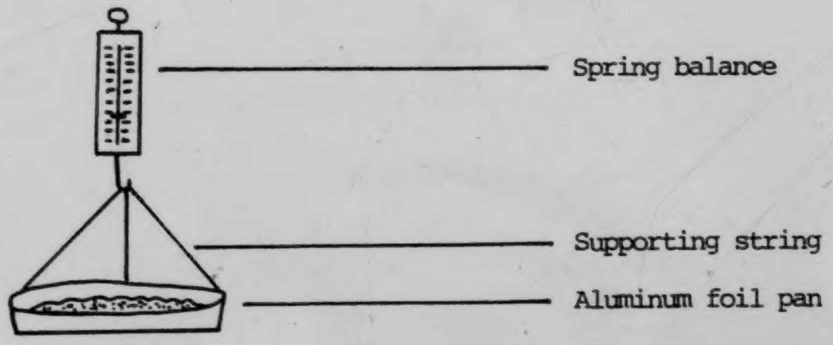
The weight of the sampler must now be measured. Attach the hook of a spring balance through the hole in the side of the sampler. Suspend the sampler and record its weight. Because no two spring balances are quite the same, use only the one that will be in your kit. Use a felt marking pen (or equivalent) and record the weight directly on the sampler.

Constructing an Aluminum Pie Plate Balance Pan

Snow is often so light that a sample you are attempting to weight makes very little impression on a spring balance. An aluminum foil pie plate, obtained at any grocery store makes an ideal lightweight balance pan.

Puncture three equidistant holes through the margin of the pan. Tie a strong piece of string 20 - 25 cm in length through each hole. Knot the three loose ends together, adjusting them so that when suspended from the hook of a spring balance the pan remains horizontal as in Figure 3. Record the weight of the pan and string with the spring balance and record this information directly on the pan. Use a waterproof felt marker or equivalent.

Figure 3. A Pie Plate Balance Pan



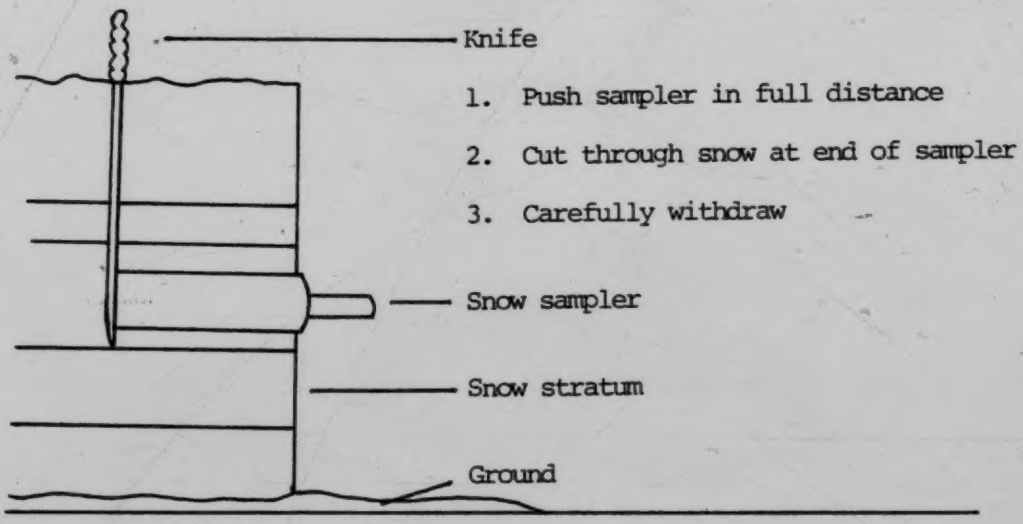
Exercise 2. Using Your Equipment

Read over this section carefully. Once in the field, you have not the time to spend reading instructions (especially if it's -20°C). If you have problems ask your teacher before going outside!

Using a Snow Sampler

Since snow forms layers, a snow sampler is pushed horizontally into the snow in order for the layers to be examined. Try not to mix snow from different layers in the sample taken. It is best to use a shovel (or equivalent) to expose a smooth side of the snow bank. The sampler is inserted as in Figure 4 below.

Figure 4. Using a Snow Sampler, Adapted from Tretiak (1973)



1. Push sampler in full distance
2. Cut through snow at end of sampler
3. Carefully withdraw

When the sampler is pushed into the snow, the holes in the back permit air to escape and allow you to see if the snow has filled the can.

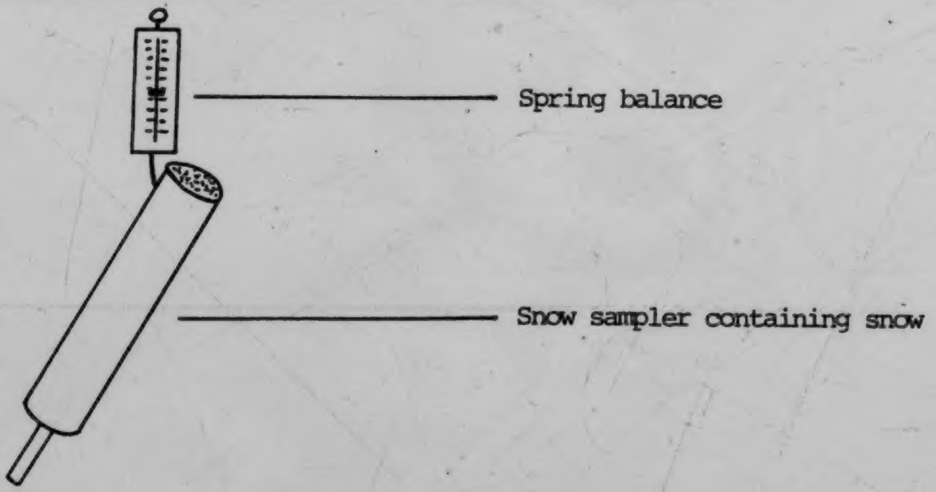
A dull knife (trowel; shovel) is used to cut off the snow so that your sample exactly fills the sampler. You have collected a precise volume of snow which can now be weighed and its density calculated.

Determining the Weight of a Snow Sample

Method 1

A number of methods may be used to weigh the snow collected by a snow sampler. The simplest is to use the sampler itself (Figure 5). Hook a spring balance through the hole in the side of the snow filled sampler and read the weight directly.

Figure 5. The Snow Sampler as a Weighing Pan



Since the weight of the empty sampler is known, the weight of the snow can be calculated. Because snow is lightweight, the combination of a heavy sampler and a low sensitivity spring balance may cause problems.

Method 2

Empty the snow in your snow sampler directly onto the pie plate pan. Suspend the pan from the spring balance (Figure 3) and record the total weight. Subtract the weight of the pie pan from the total weight to obtain the weight of the snow sample.

Exercise 3. Predictions

Before setting up a real snow station and recording actual data, examine the following theoretical situation.

The outside air temperature is -25°C. The snow in an open field is 30 cm deep. A biologist takes the following temperature readings:

a) at the upper surface of the snow (the snow-air interface)

b) half way from the surface of the snow to the ground and

c) at ground level (the snow-ground interface).

From the above information predict what you think the temperature might be. Don't worry about being exact or very accurate. Give temperatures that appear reasonable. There are no right or wrong answers. If you don't have the slightest idea, put a question mark in the space provided.

Enter your predictions on the Data Sheet No. 1 provided by your instructor.

Later you can compare these predictions to the actual results you obtain at your snow station.

Exercise 4. Snow Depth and Temperatures.

Before going outside to the study area to investigate snow depths and temperatures in the air and snow, read over the instructions carefully so that you will know what to do when you get there.

Be sure to wear appropriate clothing. Because of the cold, use pencils (have two or three available) to record data. Enter your data on the sheets provided. Keep them in a folder or attached to a clipboard for easy use and protection. Use this technique for all other studies in this series.

A list of materials you require is provided below. Your teacher will organize you into groups of a convenient size.

MATERIALS

Complete Snow Kit
Metre Stick or Equivalent
Dull Knife or Equivalent
Lightweight Shovel or Equivalent Per Person in Group
Snow Crystal Classification Chart

PROCEDURE

Select a precise location for the establishment of two snow stations. They should be in a specific environment, such as a school yard, open field, aspen grove, woods, cluster of evergreends, etc. Working procedures are described below. It is important to follow all steps in the order given. Trails to the snow station, digging in the snow, etc. disturb the natural environment. Keep disturbances to an absolute minimum.

On of the two snow stations will be called your major station and coded Station A. Most measurements will be made here. The second station, coded B, is to be located about two metres away from A and will consist of deliberately disturbed snow.

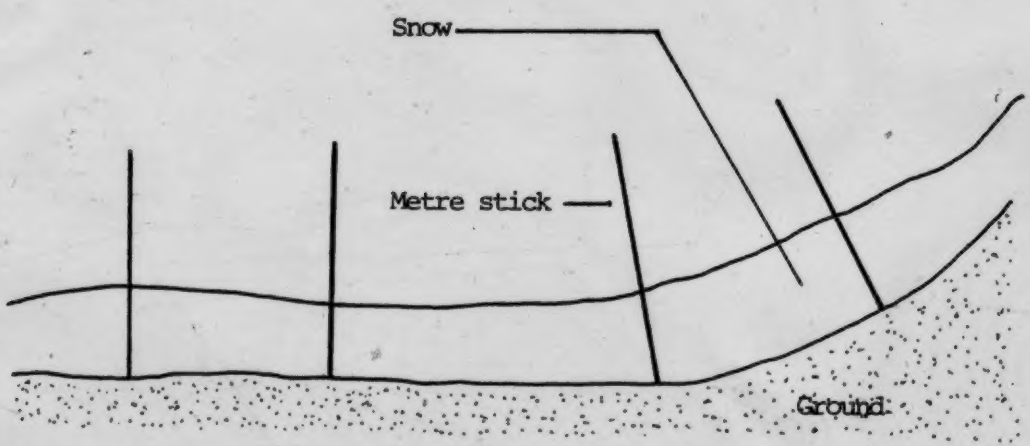
4.1 Snow Depth

Using a metre stick, one member of your group should measure the depth of the snow at Snow Station A. The metre stick may simply be pushed into the snow, perpendicular to the surface, until it contacts the ground (Figure 6). The snow depth is then recorded in centimetres. Record the depth immediately. Keep snow disturbance to a minimum.

4.2 Preparing Snow Station B

At the spot selected for your Snow Station B use shovels to break up the snow in a one square metre area. The snow can be chopped, cut, and lightly pounded. This should decrease the snow depth at this point. The station will now be left alone. It will be used at a later date for some key measurements.

Figure 6. Measuring Snow Depth with a Metre Stick

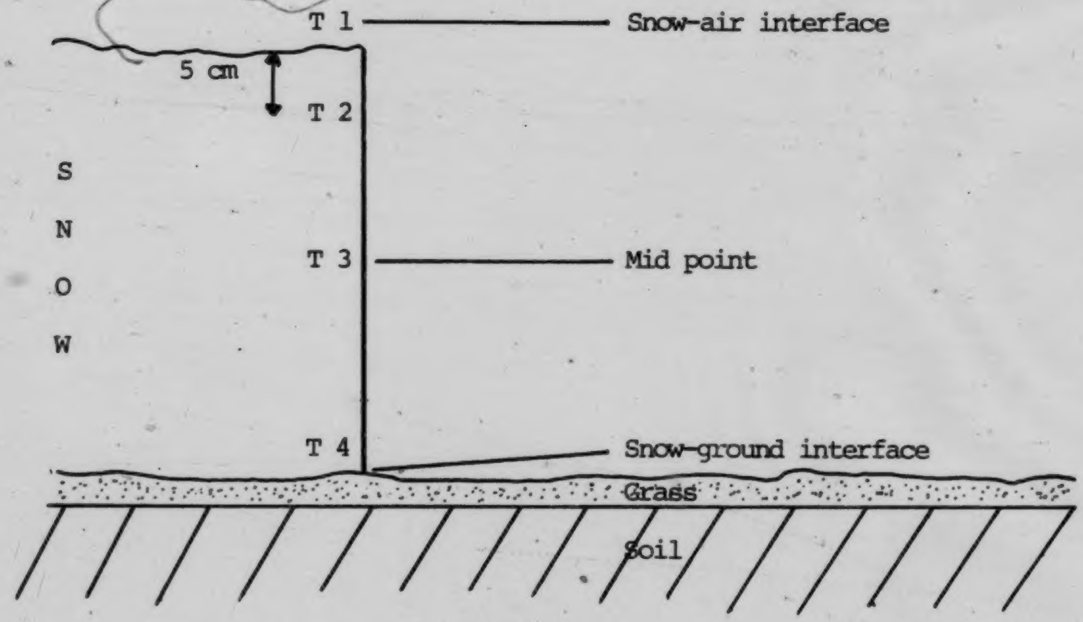


ALL REMAINING WORK IN THE EXERCISE 4 SERIES
WILL BE DONE AT SNOW STATION A.

4.3 Temperature Measurements

Refer to Figure 7 for the location of the temperature measurement points which have been designated by the letter "T" followed by a numeral.

Figure 7. A Vertical Section Through the Snow and Location of Temperature Recording Points



The snow-air interface refers to the contact point between the upper surface of the snow and the air above, while the snow-ground intervace refers to the contact point between the snow and the ground.

Temperature readings, in the snow, are taken at specific depths by inserting the thermometer into the snow at the points indicated in Figure 7.

To get to these points, a hole must be dug to the ground to expose a crossection (vertical surface) of the snow. The hole must be large enough to easily make temperature measurements. Probably 60 cm x 40 cm would be adequate.

Because the diagrams represent all possible situations, the site of your snow station, as well as snow conditions, may limit the number of temperature reading points. Record only what is possible.

Since digging a hole exposes the cut surface to the air, the temperature recordings must be done in the order outlined below to prevent the air temperature from influencing the results. The thermometer must be left in place for two minutes so that the temperature can stabilize if differences occur.

T1 - Snow-Air Interface

Record the temperature of the air at the snow surface (snow-air interface). The thermometer cannot sink below the snow surface and must be in position for at least two minutes before recording the temperature. Rest it on a piece of cardboard, paper etc. if necessary. Be sure the thermometer is shaded from the sun. Record the temperature on your data sheet.

T4 - Snow-Ground Interface/Pukak Layer

If the snow has been on the ground for some time, pukak, a special crystalline snow layer full of air spaces (or even a complete gap) may have developed at the snow-ground interface. This is called the pukak layer. If present, the temperature should be taken within this space.

Insert the thermometer, then block off the opening using a small amount of snow to prevent the outside air from entering the gap and possibly affecting the temperature reading.

If there is no pukak layer, simply insert the full length of the thermometer into the snow at the snow-ground interface. Leave for two minutes, remove and immediately record the temperature.

Record the distance from the upper snow surface to T4.

T3 - Mid Point in Snow Cover

Record the temperature within the snow half way between the snow surface and the ground. Use the same technique as above. Record the exact distance of point T3 from the upper snow surface.

T2 - 5 cm Below the Air-Snow Interface

Using the above procedure, record the temperature 5 cm below the air-snow interface. Remember to leave the thermometer in the snow for two minutes before recording the temperature.

Results and Discussion

Your teacher will provide you with special forms for entering and interpreting your field data. Read this section carefully before completing them.

Biologists use a variety of techniques to present collected data. Tables and graphs are very effective because relationships, if any, can usually be seen clearly. Maps, drawings of apparatus etc. are also helpful to anyone not familiar with what you are doing.

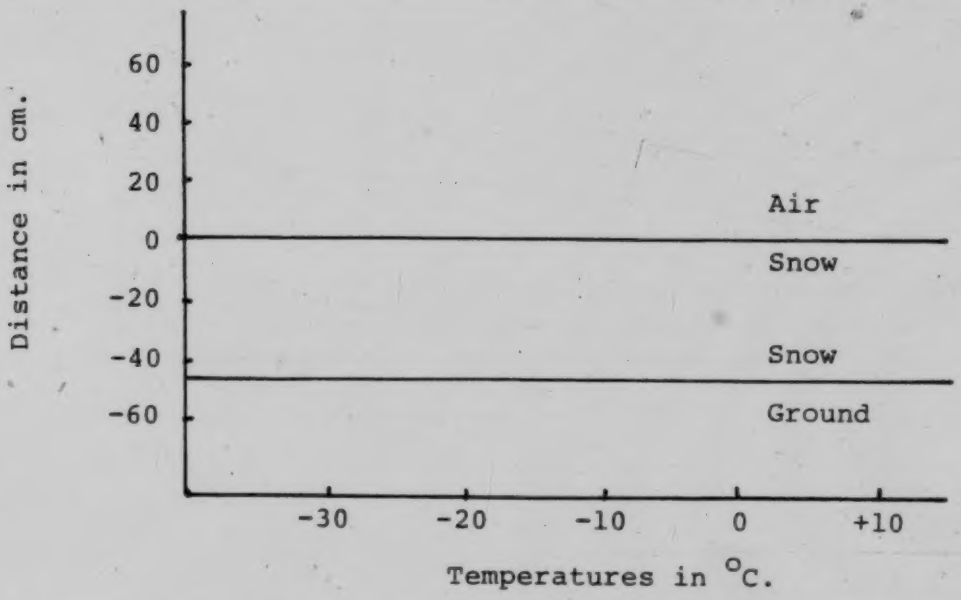
Lists of data are collected in tables, while maps, drawings and graphs are referred to as figures. Tables and figures are numbered in order of appearance and all must have a title describing their contents.

Complete the tables, figures and questions as they are found on your Results/Discussion Form. The information which follows will help you to do so.

A temperature gradient graph, developed by Pruitt (1970), is excellent for showing temperature ranges in the air and snow. It is set up as in Figure 8 below.

The temperatures (horizontal axis) obtained at the recording point at a snow station are plotted against the distance above or below the snow (snow level = 0 on the vertical axis). Once the points are joined by straight lines a quick glance reveals the pattern of temperatures in the snow. You will have some practice in making one.

Figure 8. A Temperature Gradient Graph Used to Record Temperature in Air and Snow. The Depth of the Snow is 53 cm.



Plotting Data on a Temperature Gradient Graph

Use the graph paper provided on the Result/Discussion forms. Do all work in pencil.

1. Indicate the depth of the snow by drawing a horizontal line across the graph (parallel to the air/snow line already present).
2. Above this line print SNOW and beneath it print SOIL (directly below and in the same way as the AIR/SNOW labels already present).
3. On the graph paper use a pencil to make a distinct, but not obvious, point (.) which corresponds to the temperature at the air-snow interface (T1).

4. In the same way, plot the temperatures recorded for points T2, T3 and T4 against the corresponding snow depth.
5. Using a pencil and ruler join the points, in order, with straight lines.

The Calculation of Snow Density

1. Density measures the relationship between the weight (mass) of a substance and its volume. It may be expressed by the following formula:

$$\text{Density} = \frac{\text{Weight (mass)}}{\text{Volume}}$$

$$\text{or} \quad D = \frac{W}{V}$$

For example, if an object weights 15 grams and has a volume of 5 cubic cm, its density can be calculated as follows:

D = ?

W = 15 g

V - 5 cm

$$D = \frac{W}{V}$$

$$D = \frac{15\ g}{5\ cm}^3$$

$$D = \underline{3\ g/cm}^3$$

You now know that the object weighs three grams for each volume unit.

2. To calculate the density of snow using a snow sampler, weigh the empty samper with a spring balance and permanently record its weight before you establish the snow station. When a snow sample is taken, weigh the sampler with the snow in it. Simple subtraction will give you the weight of the snow as follows:

   Weight of sampler and snow - Weight of sampler empty = Weight of snow

If a pie plate pan is used, the method of calculation is the same. Simply replace the word "sampler" with "pie plate pan".

You have already recorded the volume of the sampler which will naturally equal the volume of snow you collect in it. Simply divide the snow weight by its volume to obtain the density.

Here are some data obtained at a snow station and how they were used to calculate the density of the snow sample.

Weight of sampler = 25 g

Volume of sampler = 40 cm^3 = volume of snow

Weight of sampler and snow = 45 g

$$\text{Weight of snow} = \text{weight of sampler and snow} - \text{weight of sampler}$$

$$= 45\text{ g} - 25\text{ g}$$

$$\text{Weight of snow} = \underline{20\text{ g}}$$

$$\text{Density of snow} = \frac{\text{weight of snow}}{\text{volume of snow}}$$

$$D = \frac{20\text{ g}}{40\text{ cm}^3}$$

$$D = \underline{0.5\text{ g/cm}^3}$$

When all your work is completed, attach Data Sheet No. 1 to the Results/Discussion pages, add an appropriate title page and submit the report to your instructor.

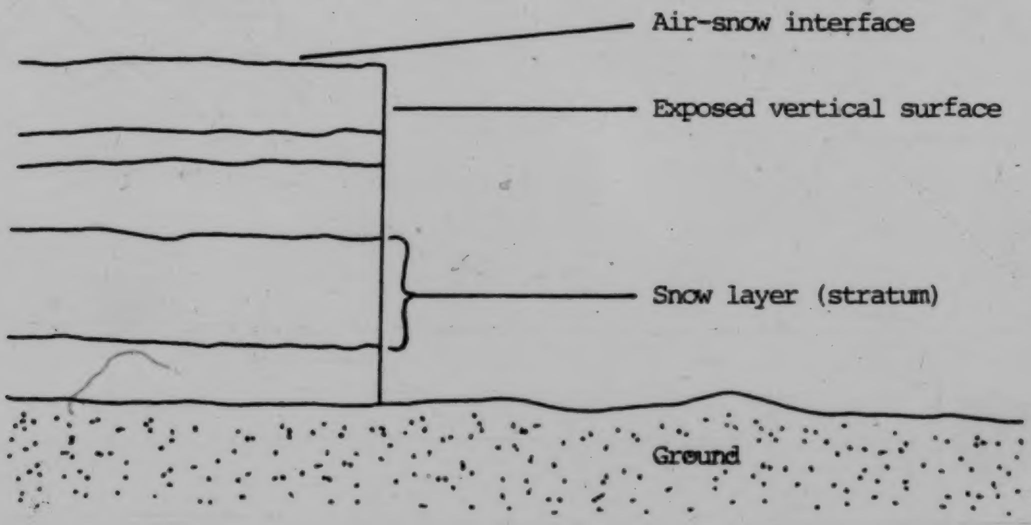
Exercise 5. Other Snow Station Measurements

Except where noted (Exercise 5.4) all work is to be done at Snow Station A.

5.1 - Snow Profile

Because time usually occurs between snowfalls and conditions during each fall are somewhat different, a crossection through the snowpack usually reveals distinct layers or strata (one layer - a stratum). This is illustrated in Figure 9. Each stratum usually represents a single snowfall. To make a profile use a shovel to make a clean vertical section down one side of the hold previously dug in the snow (Procedure 1) so that the layers of snow, if any, are visible. Using a fine brush (ie. paint brush), carefully brush the side clear of any loose snow. This should clearly reveal the layers.

Figure 9. A Crossection Through the Snow Illustrating Snow Layers (Strata)



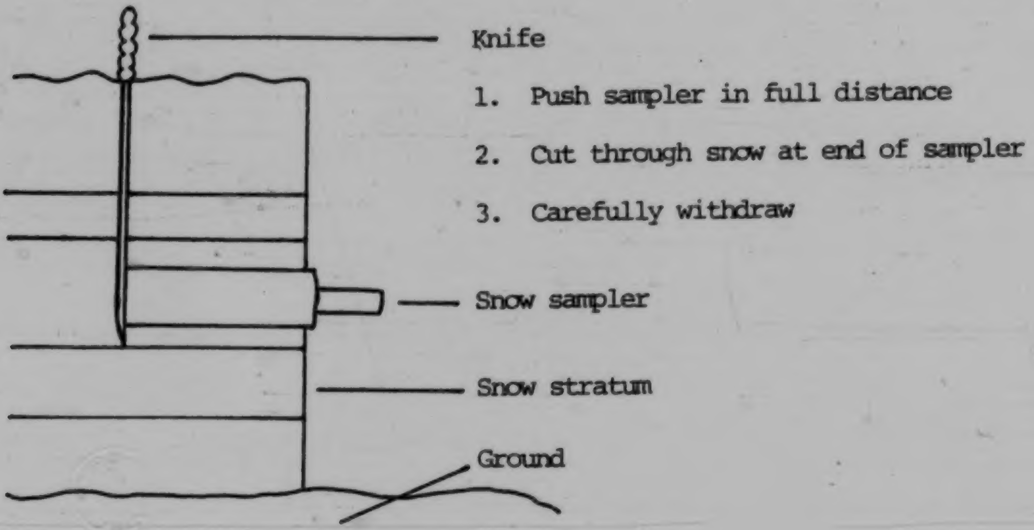
Record the number and thickness of all layers present on your data sheet. Make comments on your observation if appropriate.

5.2 - Density

In order to calculate snow density, a snow sampler of known volume is required. The mass (weight of the sampler of snow) is recorded and the density calculated. The construction of a snow sampler and some techniques used in determining the mass (weight) of snow have already been outlined. You must decide on a method before you begin this exercise. Record the volume of the sampler on your data sheet before going out into the field.

Using the snow sampler as shown in Figure 10, collect samples from the upper, middle and bottom of the snow. Depending on the snow profile and depth, the density of the upper and lower snow layers may be the only possible measurements. The snow depth and diameter of your snow sampler will determine how many measurements are possible.

Figure 10. Using a Snow Sampler, Adapted from Tretiak (1973)


Knife
1. Push sampler in full distance
2. Cut through snow at end of sampler
3. Carefully withdraw
Snow sampler
Snow stratum
Ground

The calculation of snow density will be done in class.

5.3 - Snow Crystal Structure

Snow crystals from each level tested with the snow sampler may be examined with a hand lens and their structure recorded. The snow crystals may then be classified according to an accepted standard such as the system described in LaChapelle's book, Field Guide to Snow Crystals. A simplified version has been provided.

Place a few crystals on a surface (glove, booklet, etc.) and examine with a hand lens. Determine the type of crystal and record its age number on your data sheet.

5.4 - Density - Temperature Relationship

In this activity you will be using both Snow Station A and B, recording the same type of measurements at both, and then comparing the results.

5.4.1 - Temperatures

Using the same techniques you used in your first temperature measuring exercise (4.3).

a) Recording the air temperature at the snow-air interface half way between the two stations. This should give you an average air temperature. (Remember to shade the thermometer.)

b) Cut back the vertical wall of Station A an extra 30 cm to expose a fresh face. Immediately take the temperature under the snow at ground level (leave the thermometer inserted for two minutes) and record.

c) Take the temperature in the snow at a point mid way between the upper surface and the ground. Record.

d) Cut a vertical section throught he packed snow at <ins>Station B</ins>. Immediately record the temperature under the snow at ground level.

e) Record the temperature in the snow at the mid point between the upper surface and ground at station B.

5.4.2 - Densities

Since you have already recorded snow density data from Station A, use the following instructions at Station B only.

a) Use the snow sampler to determine the weight of snow just below the upper surface. Record your data.

b) Take a second sample just above the ground level and record your results.

Results and Discussion

You will now be provided with special forms for entering and interpreting your field data.

When completed, attach Data Page No. 2 to these Results/Discussion pages and give them to your instructor.

Preceed your report with a title page.

WINTER ECOLOGY ACTIVITIES
FOR USE IN
SECONDARY SCHOOL SCIENCE

PART II

Introduction

Very little has been written about the ecology of organisms in winter, with the exception of few researchers who report their work in scientific and technical journals. As a result, even less ecological information has made its way into biology textbooks. Considering that half a year is spent in a winter-like environment, it is amazing that winter's effects on organisms is not very well covered. As the north opens up to more activity and settlement, knowledge in this area is definitely a requirement.

Fortunately, reading material is finally becoming available. Your first assignment in Part II of your activities will involve reading two articles on basic winter ecology.

Exercise 6. Readings in Winter Ecology

Read the two included articles carefully. Try to note how the data you have collected and studied corresponds into the information in the articles. Pay particular attention to the descriptions of snow effects on organisms, an area you will be investigating shortly. After you have read the articles you will be given a brief assignment based on the information presented. If there are terms you do not understand, check the glossary at the end of the booklet or refer back to the list of Inuit snow terms (Table 1, page 2) for clarification.

Article 1. Tretiak, A. 1973. An adaptation of an article entitled "Snow Ecology - Some Basic Information".

Article 2. Pruitt, W.O. 1975. An adaptation of an article entitled "Life in the Snow".

Snow Ecology: Some Basic Information

Adapted From Alex Tretiak

Alex Tretiak, A Manitoba science teacher, prepared the original article for the Manitoba Department of Education in 1973.

For approximately half of the year, most areas of this country are subjected to the continuous presence of a blanket of snow, which gradually increases in thickness as the winter progresses, and then rather suddenly disappears with the return of longer days in the early spring. This is the half of the year that most people would like to forget, as it is the period of miserable walks from the house to the cold car, of shovelling the driveway or sidewalk, and of daydreaming about the blue waters and green forests of the summers past and the summers to come. Our lifestyle is frequently designed to avoid the outdoors during this time of year, and when we are forced to be out for any length of time, it is often considered a feat of endurance to have "survived" our exposure once again!

The various media have conditioned many of us to this type of response. The news media tell us it is terrible outside if it is snowing. When people step outside in the clothing that was designed for winter, they often find out the clothing was designed for new winter styles, not the conditions of our local winters which are anything but new. A change of attitude is necessary if we are to discover what winter really has to offer. Nothing is further from the truth than the notion that life in the natural habitats grinds to a near-halt with the onset of winter.

Snowfall

The snowflake that gently falls to the ground and settles among its predecessors has just completed a complicated journey through the atmosphere. This solid form of precipitation begins as water vapour in the atmosphere. When the air containing this vapour is sufficiently cooled, some of the vapour condenses to form clouds. We are able to see this portion of the moisture in the atmosphere. Under suitable conditions, these cloud particles, which may be water droplets or ice crystals, depending on the temperature, collect around condensation nuclei (dust particles or salt crystals) in the atmosphere and grow in size. Once these particles have reached a certain size, they start to fall to earth. As the snowflakes descend, they pass through layers of air that differ in temperature and moisture content. These crystals may continue to grow, and become altered by the conditions that exist in the air through which they pass. Once these crystals have reached the ground, a close examination of them will reveal great diversity of form as a result of the temperature, moisture and winds they have encountered during their descent. The two features that will be common to a particular snowfall will be the diversity of forms of crystals and the six-sided nature of the crystals. As subsequent snowfalls will have originated from different air masses, the flakes that are produced are somewhat different. This will produce layers of snow on the ground that will differ from previous falls. Vast numbers of flakes must accumulate in order to produce snow of any depth. Up to tens of billions of flakes are required to produce one cubic meter of snow.

Permanent Snow

With the appearance of permanent snow on the ground, other factors now come into play and modify this cover. The type of snow cover that will result depends on the terrain, vegetation, wind action, amount of snow on the ground, and certain maturation processes that occur within the snow. One end result of all this is the unequal distribution of snow on the ground. This is an important factor in the lives of the mammals that have a very intimate relationship with the snow on the ground.

One of the most obvious physical properties of snow is its density. It has a very low density. The larger the flakes the lower the density as the spaces between the flakes become larger. Snow resulting from large flakes has an average density of about 0.05, middle-sized flakes about 0.09, and small-sized flakes about 0.13. Water has a density of 1.0 and ice approximately 0.9. Snow lying on the ground slowly becomes transformed and the density of it changes with time.

The most important property of snow is its ability to insulate. As snow consists mostly of air, it makes an excellent insulator. It is this property of snow that allows for the survival of the small-mammal population during the winter. With the approach of winter, the ground gradually cools and freezes at the surface. If there is little or no snow cover on the ground, the ground continues to freeze to a greater depth. This is a very critical time for the small-mammal population, as they have difficulty maintaining their body temperature when exposed to such cold air.

Once there is an adequate snow cover on the ground, the cold air above the snow is isolated from the soil below. Heat from further down in the soil is transferred to the top of the ground and, as a result of this, the temperature under the snow just above the soil is not much below the freezing point. Here, then is an environment created by the snowfall which reduces the severity of winter. It offers protection to the small-mammal population, prevents plants and invertebrates from freezing, and even is important for the survival of winter grain crops that man has put in. This borderline zone between the two environments is called an ecotone, or zone of sharp transition. Beneath the snow is a new world that is dark, silent, warm and moist. There is no difference between night and day and very little change, if any, in temperature when the air above the snow may range from -1 degree C. to -50 degrees C. The passage of time is not marked by any fluctuations in this subnivean (below-the-snow) environment. It is, in a sense, almost timeless.

Transformation of Snow

The English language lacks suitable terms to describe the different conditions of snow. Both the Indians and Inuit have developed a rich vocabulary of terms that describe the various types of snow. As snow plays such an important role in their lives, it is necessary to communicate the exact conditions that exist during the winter. The Kobuk Valley Inuit of Alaska have such a terminology, and it is incorporated in the text which follows.

Snow, or Anniu, begins to become modified as soon as it reaches the ground. This snow on the ground is referred to as Api. In windy, exposed country, such as the tundra, snow is blown away from elevated areas and is packed into depressions. This blowing snow is called Sicoq, which means drifting or smokey snow. The snow crystals become abraded into very small particles, and their accumulation results in drifts of considerable hardness, known as Upsik. In the tundra, these drifts are known to become so hard that a tractor can drive on them and the cutting of the snow with an axe becomes extremely difficult. A saw is the recommended implement for cutting the snow into blocks in such an area. It is obvious that the density of the snow has been increased considerably and, as a consequence, its insulating properties have decreased. The presence of these drifts can influence the vegetation that appears in the spring. Plants under a drift are provided with shelter from the intense cold and supplied with adequate moisture for spring growth. However, if this drift is too large and sheltered from the sun, it takes too long to melt and growing season becomes inadequate for plant growth. Wind action thus results in the uneven distribution of snow on the ground. One good feature of this action is the appearance of low tundra plants through which such snow cover provide birds, such as Willow Ptarmigan, with food.

In sheltered terrain with little wind, snow is not modified to such a degree as on the tundra. Thus in the taiga or coniferous forest, snow remains on the ground to be altered by forces other than wind. In a forest, trees intercept some of the falling snow. The snow that collects on the trees is known as Qali.

Below the tree is a snow shadow with the amount of snow on the ground decreasing as you move closer to the trunk of the tree. This bowl-shaped depression in the snow around the base of the tree is called a Qamaniq.

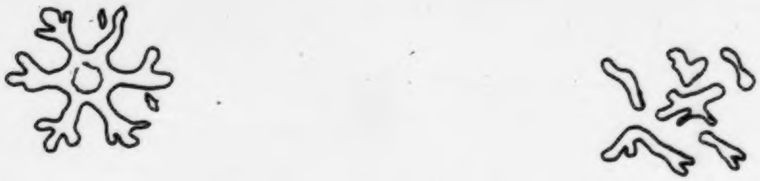
Since there is less snow around the base of the tree, its insulation is poor and the area below the trees is not frequented by the small mammals in cold weather because of much lower temperatures on the surface of the soil. These areas of little snow are frequented by a variety of terrestrial birds in search of food.

The addition of snow to the branches of the trees also lessens the influence of any wind in the forest below, thereby helping to make the forest a more stable environment. When a wind of sufficient strength dislodges the Qali, the snow surface below becomes pitted with Qali craters. This wind may cause some drifting below in the more exposed areas.

Several processes alter the nature of the undisturbed snow. The sun acts on the surface of the snow in mild weather and can produce a suncrust or layer of ice. This thin layer of ice is called Siqoqtoaq and is noticeable when the sun's reflection off the surface of the snow is very bright. During a mild spell, a light rain may also form a crust of ice over the snow. Another name for an ice crust is Nast, a Russian term.

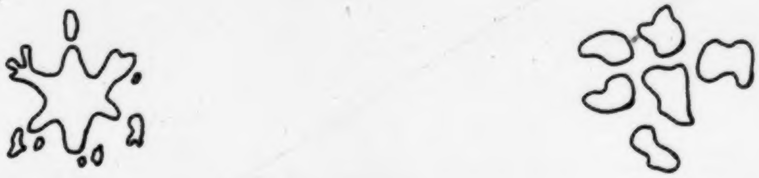
Snow crystals have very unstable shapes and tend to change so that the ratio of surface area to volume is reduced. The change occurs by the transfer of water molecules from one part of the crystal to another.

Figure 11. Changes in Snow Crystal Form in the Snow Pack (from LaChapelle 1969)



1. Original crystal forms easily distinguishable

3. Original forms fragmented and no longer recognized; fine-grained old snow



2. Original forms distinguishable with difficulty

4. Rounded ice grains

A major transformation of the snow occurs because of the nature of the soil it lies over. The temperature and moisture content of the soil is greater than that of the snow above it. Hence, there is a flow of heat and moisture upward from the soil through the snow cover. Through the process of sublimation, there is a transformation of the crystals within the snow. Water molecules leave the tips of the small crystals and attach themselves to the larger crystals. It is called temperature-gradient metamorphism when large crystals are produced near the base of the snow cover that has grown at the expense of the small ones. This granular layer is now known as Pukak, or depth hoar, and it contains many open spaces just above the soil. This is the area of activity of the small mammals during the winter.

With this change in the nature of the snow cover, there is also a change in the density and hence its ability to insulate.

Life in the Snow

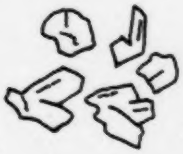
by William O. Pruitt, Jr.

Dr. William O. Pruitt is a member of the faculty at the University of Manitoba, Department of Zoology. He is one of Canada's foremost authorities on the ecology of the North. The following material has been adapted from an article which appeared in *Nature Canada*, Volume 4, Number 4, 1975.

If snowflakes were rare objects, generations of graduate students would doubtless have received degrees for research into the properties and potential uses of snow. As it is, some tens of billions of these beautiful crystals of frozen water vapour pile up in each square metre of snow of even moderate thickness. In greater or lesser thickness snow covers more than half of the land area of the Northern Hemisphere at some time during the year. In centres of civilization, it is welcomed with shovel and snowplow; labour and equipment are speedily mobilized to clear it from sidewalks, streets, driveways, highways and airstrips. The very abundance of snow seems to have suppressed almost all but this negative interest in getting rid of it as

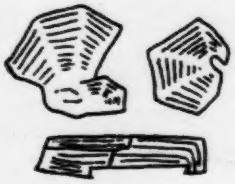
Figure 12. The Growth of Snow Crystals in the Snow Pack Due to Heat from the Earth (from LaChapelle 1969)

1. Angular crystals, non layered
   (begins in new snow)



2. Small and poorly formed layered
   crystals

3. Mature, fine or medium grained
   depth hoar, prominent layering



quickly as possible. In the literature of the sciences that ought to be concerned, there is little to suggest that snow is a major element in the environment of life.

To our way of thinking, snow would seem principally a hindrance to the locomotion and food-getting of animals. The onset of winter is the occasion for spectacular southward migration of birds and mammals. But many creatures, by anatomy and behaviours, have become adapted to survive in snow cover that may persist for nine months of the year. Some have developed snowshoes or stilts that permit them to move freely above the snow. Others have found refuge beneath the snow cover and there have occupied a dark, damp and silent world with a constant climate warmer than that of the world above.

The biologist, who sets out to study the role of snow in the life history and distribution of animals, must first learn something about snow itself. A snow cover is by no means simple and homogenous. The snow cover varies greatly in texture and structure from place to place and presents sharply contrasting environmental situations. On this diverse subject, the wisest instructors are the sub-arctic Indians and the Eskimos. Long ago they fashioned quite different technologies to take advantage of the special properties of the snow cover in the regions they inhabit. They each succeeded, for example, in making snow do the service of the wheel. On the wind-hardened snow of the open Arctic tundra the Eskimo sled, or "Komatik", rides upon runners and is unsurpassed in lightness, ruggedness and ease of pulling. For the thick, fluffy snows of the boreal coniferous forest, or taiga, where the komatik would bog down, the Indians created the runnerless toboggan. The Eskimos built snug houses quickly and easily from shaped blocks of the hard tundra snow, though many of the Eskimos have now lost the art. To build a snow house in the soft taiga snow, the Athapaskans and Chipewyans first heaped up a huge mound of snow, allowed it to harden or "set" and then hollowed out a cavern inside. Every winter my students learn to build such snug shelters called "Quin-Zhees".

On the snow-covered tundra, the Eskimo can walk almost anywhere without sinking, but in the forest, the Indians had to devise snow-shoes - small ones with coarse-meshed webbing for relatively dense snow-cover and long, broad ones with fine-meshed webbing and turned-up tips for a thick cover of light snow. The rich lore of snow that underlies such ingenious adaptations is reflected in the languages of the northern peoples. Each of these languages offers concise words to designate particular aspects of snow which, in English, call for cumbersome descriptive phrases. I have found many of these words more suitable than the "official" meteorological terms for specifying snow conditions in their relationship to the life of animals that inhabit snowy regions.

The variations in snow cover begin with the formation of the snow as it falls. In temperate and cold-temperate climates, as atmospheric moisture sublimes directly from the vapour to the solid state, the snowflake builds up as a six-armed star of hexagonal plates with a thickness of about 0.1 millimeter and a diameter ranging from one to five millimeters. Through aggregation as they fall, such snowflakes may form extremely complex structures. In the arctic or sub-arctic, snow falls more frequently as neeles or tiny prisms, ranging in length from 0.1 to three millimeters and in diameter from 0.01 to 0.2 millimeters are formed. From the moment they come to rest on the earth or upon snowflakes that have preceded them the delicate stars and flakes change their shape.

The taiga snow, on which my work has centered, may best be visualized as an emulsion of air and ice, with the volume of air far exceeding that of the ice. New-fallen taiga snow may have a specific density only five per cent of that of water. Beneath the snow cover as a rule, the soil is warmer than the air through which the flakes have fallen. Heat and moisture, therefore, flow upward from the soil through the snow. These temperature and vapour-pressure gradients play a crucial role in the history of the cover. Though sublimation, molecules of water leave the attenuated tips while the corners of the flakes below attach themselves to the tips of flakes above, which are colder because they are farther from the soil. In this process, the larger and more massive flakes also grow at the expense of the smaller and more delicate ones. Eventually, the bottom layer of the cover assumes a coarse granular structure - "pukak" in the language of the Kobuk Valley Eskimos of Alaska. The snow particles next to the ground may in time be completely eroded away, leaving a vacant space with fragile, lattice-like walls and roof.

As the cover thickens with successive falls, its lower layers are compressed. Each snowfall, originating in a unique sequence of meteorological events, is somewhat different from all others. Thus, each layer is made of a different type of flake or grain and has a different thickness, hardness and density. The passage of a warm moist air-mass, bringing thawing temperatures and perhaps even a light rain, will increase the moisture content and density of the uppermost centimeter or so of snow. The succeeding cold air-mass will freeze the moisture and the snow cover will now possess a hard, dense top-layer, or even a crust of ice. This layer may be buried by subsequent snowfalls. If it is dense enough, it may be impervious to the passage of air and water vapour and so will cause a change in the steepness of the moisture and heat-flow gradients in the cover. Marked fluctuations in the air temperature during the accumulation of the cover will thus set up complex gradients and a succession of ever-changing densities and hardnesses within.

Later in the winter, a windstorm may sweep over the snow. Reaching down through the sheltering spruce trees of the taiga, the wind picks up the surface flakes and tumbles them about, abrading their delicate points and reducing the flakes to shattered remnants. With their smaller size and simpler outlines, the particles nest more closely together, forming a hard, dense layer. If this reworking of the cover is confined to the surface, it forms a "wind slab". If it involves the entire depth of snow, as happens regularly on the tundra, the cover is transformed into a hard, dense mass ("upsik") capable of supporting the weight of a fox, wolf, caribou or man.

As the snow whispers down through the spruce trees, a significant portion of it remains caught in the branches. The snow that clings to the trees ("qali") often accumulates in quantities sufficient to bend and break mature spruces. Indeed, there is evidence that in the interior of Alaska, breakage by qali initiates the cycle of forest succession that gives the taiga there its characteristic mosaic of evenly aged stands of spruce interspersed with stands of variously aged willow, alder and aspen. With so much snow caught in the branches of the spruce, there develops around the base of each tree a bowl-shaped depression in the cover, called a "qamaniq". The soil may be bare at trunk, and the snow gradually increases in thickness outward from the tree. At the tips of the branches the "snow shadow" ends, and the thickness of the snow increases abruptly.

As the days lengthen in the spring, sunlight striking down through the trees melts the top layer of snow. Upon freezing at night, the soggy surface forms a "sun crust", or "siqoqtoaq". In high altitudes and latitudes, where the coming of spring brings lengthening periods of intense sunlight with the air temperature still far below freezing, the surface flakes are transformed into long vertical spicules called ablation needles or "qulu".

For most birds and several of the larger mammals, the snow cover means deprivation of food supply. Their behavioural response to this ecological challenge is to flee the country that is ideally suited in spring and summer for their reproductive period - the most vulnerable in their life cycle. Investigation has shown that in most cases these animals can withstand the prevailing winter temperature of the regions they abandon, if they are provided with sufficient food. It must, therefore, be their inability to procure food from under the snow that induces their mass exodus. Among birds, the migratory species are principally insect-eaters and ground feeders; among mammals, the most notable migrators are the elk and the gregarious caribou.

I have found that the winter distribution of caribou is regulated quite precisely by the character of the snow cover. Most of them abandon the tundra and its hard-packed snow-cover in the autumn and migrate to within the tree line. Aerial surveys of wintering bands of caribou, combined with on-the-spot analyses of the snow-cover, show that these animals concentrate where the snow is soft, light and thin, permitting them to dig through it easily to uncover the food below. These areas are bound, as if by a fence, by areas where the snow is hard, dense or thick. The critical hardness, expressed in terms of capacity to bear weight, seems to be around 60 grams per square centimeter. The corresponding specific density ranges upward from sixteen per cent of that of water to that of ice (which of course has a density somewhat less than that of water), and the fence-forming thickness of snow is about 60 cm. In the course of a winter, the caribou bands may be seen to move about in accordance with the shifting of the fences of unsuitable snow.

In contrast to the caribou, the moose is an examplar of anatomical adaptation. Its long legs reach down through the snow cover to the firm ground beneath and carry its belly well above the surface. When the snow cover attains a thickness of about 90 cm, however, stilts no longer suffice. At such times, the moose packs the snow in trails or "yards". The alternative to the stilt is the snowshoe, and the classic example of this adaptation is the oversize feet of the varying hare. But whenever the hardness and density of the snow fall below a critical level, the hare, too, turns to packing the snow to form regular trails and runways.

Temperature, as well as snow cover, is an important factor determinig the behaviour of animals in the northern winter. Only the larger mammals, the hare, fox, wolf, lynx and moose are metabolically able to withstand the extremes of cold and live above the snow surface. Smaller mammals, such as shrews, voles and lemmings, have such a small body mass with respect to their heat-dissipating body surface (and such comparatively inefficient fur) that their metabolism cannot maintain normal body temperature. Their survival in the taiga winter climate is made possible only by the behavioural adaptation that causes them to seek shelter under the taiga snow cover.

Snow is such an effective insulator that the temperature of the mossy floor of a mature spruce forest seldom drops below -7°C., even though the air above may fall to -40 or -50°C. In the interior of Alaska, I was once unable to detect any temperature change during a period of nine days at a spot in the forest floor under a cover of 75 cm of snow, even though the air temperature above fluctuated between -4 and -33°C. Freshly fallen, fluffy snow has a thermal conductivity of only 0.0002 calories per square centimeter per second through a gradient of one degree centrigrade. Thus vegetation, small mammals and hibernating or pupating insects are protected from the violent temperature changes that characterize the climate above the snow cover.

Small mammals disappear below the surface in the autumn when the snow cover has built up to a thickness of about 15 cm. The temperature of the moss and the soil at this time ceases to follow the fluctuation of the air temperature. A.N. Formozov, the distinguished Russian naturalist, has observed the same threshold in the activity of small mammals of the taiga in the U.S.S.R. In the cycle of the seasons, the "Fall Critical Period", the period between the onset of subfreezing temperatures and the development of the snow cover to the hiemal threshold, undoubtedly gives shrews, voles and lemmings their severest trails.

Although the temperature under the snow cover remains stable from day to day, the temperature of the forest floor varies strikingly from place to place. One would expect, for example, that the qamaniq under the snow shadow of the spruce would be cold spots. I have found this to be true. With the air temperature at -31.5°C, the soil temperature one inch below the surface was -19°C at the base of a tree and -12.5°C just below the qamaniq. Later in winter, with the air temperature at -36°C, the temperatures were respectively -21.5 and -12°C. The activity of the small mammals under the snow relects this pattern of temperature at the forest floor. Sampling of the population, by means of live traps under the snow, shows that red-backed voles avoid the qamaniq in favour of those parts of the home range under full snowcover. The Russian worker, N.V. Bashenina, has shown that carbon dioxide gas sometimes accumulates under a taiga snow cover in concentrations sufficient to cause voles to construct "ventilator shafts" up through the snow. At the openings of these shafts, the voles are exposed to predation by owls. Formozov believes that it is this habit of the vole that permits certain species of owls to survive the taiga winter.

Since snow is an excellent insulator against sound, the winter environment of the voles and shrews is silent. It is also dark, because a 30 cm snow cover transmits only eight per cent of the incident light and a 60 cm snow cover only one per cent. The air beneath the snow is calm and essentially saturated with moisture. Hovering between -10 and -4°C. for most of the winter, the temperature varies quite slowly. The subnivean environment is thus strangely removed from the taiga winter above the snow with its brilliant days and moonlit nights, its relatively sudden and violent temperature changes, and its winds and forest noises. By diverse bodily and behavioural adaptations, the small mammals of the taiga are able to utilize this environment and survive the northern winter. Without the snow cover the region would be deprived of most of its mammals.

There is one mammal, the familiar red squirrel, whose size and weight place it just between the two groups that live respectively above and below the snow. When the deep cold of the taiga winter settles over the spruce forests of the north, the red squirrels shift the locus of their activity from the trees above the snow to subterranean tunnels below the snow. For weeks at a time, no red squirrels will be seen in the forest. The critical temperature that sends them from the environment of the moose, fox and lynx into the environment of the shrew and red-backed vole seems to lie between -32 and -34°C.

We are indebted to Formozov for the scheme that classifies mammals on the basis of their adaptation to snow. Those animals that are unable to adjust to snowy conditions he calls chionophobes, from chion, the Greek word for snow. In North America, the pronghorn, the wild turkey and the opossum belong to this category. Chioneuphores are animals, such as the shrew, fox, vole, moose and elk, which can survive in snowy regions. The small select group of animals, such as the varying hare, the North American caribou and the varying or "hoofed" lemming, which possesses definite adaptations for snow and is limited to snowy regions, is known as chionophiles. This ecological classification has great possibilities as a tool in zoogeographic studies and should also underlie all wildlife management programs in snowy regions.

Exercise 8. The Snow Shelter and the Subnivean Environment.

From the first investigation plus assigned readings, it should be evident that it is warmer under the snow than above the snow during cold weather. As a result, the presence of snow in the Canadian winter serves to protect organisms found beneath the snow from some of the severe temperature extremes which we normally expect during the winter season. Many small mammals and insects, which people assume are hibernating, are really quite active under the snow cover where it is reasonably warm. New fallen snow is generally light and fluffy. The shape and structure of the individual snowflakes cause air to be trapped between the crystals. This low density snow becomes an excellent insulator and prevents heat rising from the earth from rapidly escaping. It may be accurately compared to the wearing of a down jacket.

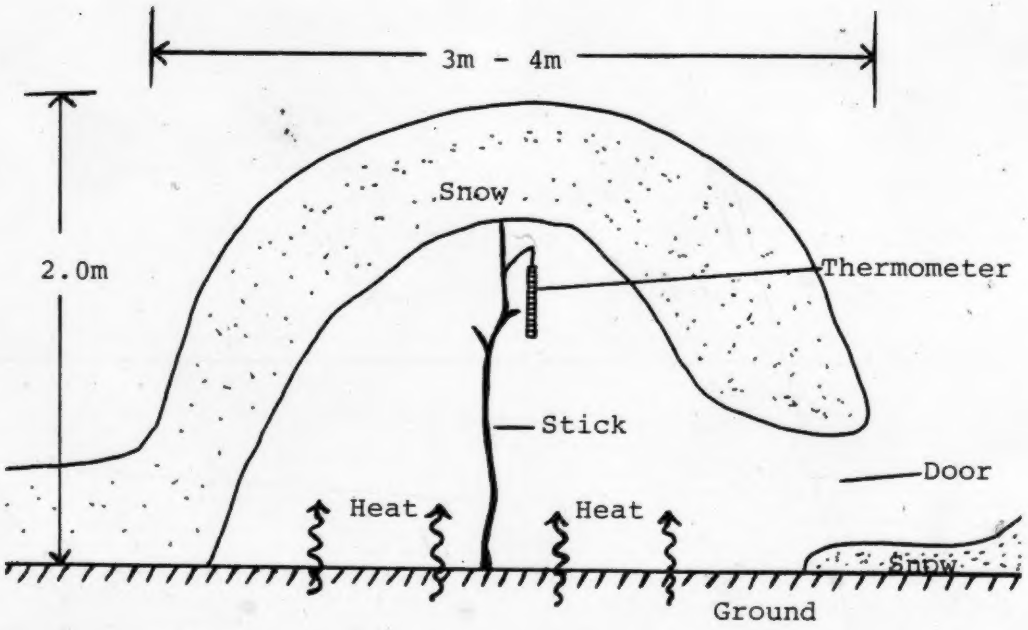
Both the Inuit and Northern Indians have used the above principle to consrtuct snow shelters. The Inuit are famous for the now rarely used "snow igloo" made from densely packed snow (typical of the tundra regions) which is hard enough to be cut into rigid blocks. These blocks are easily handled and provide considerable insulation even though the snow density is quite high and its insulation ability reduced.

Snow, in the boreal forest regions (taiga) that make up most of Canada, tends to be softer and cannot be used to construct "igloos". The Chipewyans and the Athapaskans, northern Indian groups, developed a unique snow shelter called a quin-zhee, which allows man to use the insulation properties of snow.

This creates an environment similar to that of typical subnivean (beneath snow) plants and animals. By constructing a quin-zhee, you can investigate the environment of the subnivean organisms in an indirect way and also determine the effectiveness of a snow shelter.

The quin-zhee (Figure 13) is constructed in the following manner.

Figure 13. Cross Section Through a Quin-zhee (Snow Shelter)



Using a lightweight shovel, snowshoes or some other "digging" device, snow is piled about 1.5 - 2.0 metres high and 3 - 4 metres in diameter. It is important to obtain snow from all depths. Because snow at depth is warmer than the upper layers, the resulting mixture causes the snow crystals to fuse together. It takes as little as 25 to 30 minutes for the snow to "set" on a very cold day (-20°C) and on to two hours on warmer days (-5°C to -10°C).

A small hole (door) of body diameter is dug into the snow pile, close to the ground and a cavity hollowed out. The snow is scraped clear to the ground. The walls and roof should be at least 40 cm thick.

A piece of cardboard, old towel, styrofoam, etc. may be used as a door cover. Indians would often use the skin of some animal.

Before going outside and building a quin-zhee, try the following exercise.

A quin-zhee was completed as in Figure 13. The outside (ambient) air temperature is -25°C. A series of temperature readings are taken 10 cm below the roof inside the quin-zhee under varying conditions. For each of the conditions try to predict what the temperature readings might be. Don't worry about being accurate. Record your predictions on the data sheet provided by your instructor.

Condition 1. The door of the quin-zhee is open to the air.

Temperature =

Condition 2. A piece of cardboard is used as a door. The door remains shut for six minutes.
Temperature =

Condition 3. A person remains in the quin-zhee, with the door closed, for five minutes.
Temperature =

Condition 4. Two people remain inside, with the door shut, for five minutes.
Temperature =

Now transfer your predictions to the data sheet provided for this activity. It is now time to investigate the characteristics of the quin-zhee.

Before following the procedure for this investigation be sure you have all the required materials listed below.

Materials

Shovels - lightweight aluminum if possible (if you wish to integrate the building of the quin-zhee with survival techniques, replace the shovel with snowshoes, cross-country skis, etc.)

Cardboard, Styrofoam, or Old Towel - for use as a "door".

Thermometer - alcohol, with supporting string.

Flashlight - for reading thermometer "in the dark".

Snow Sampler

Ground Sheet - for protection from melting snow on the ground; a garbage bag or plastic sheet is quite satisfactory.

Stick or Hook - to support the thermometer 10 cm from the roof.

Metre Stick - or equivalent.

Watch with second hand or stop watch.

Procedure

Construct a quin-zhee as previously described. Pile the snow as quickly as possible. Be sure to let the snow set for at least thirty-five minutes before hollowing it out, or else the snow will collapse.

When the quin-zhee is complete support a thermometer 10 cm down from the roof as in Figure 13. Record temperatures inside the shelter under the conditions outlined below. First record the outside temperature.

1. Leave the quin-zhee empty and the door open for six minutes, then quickly enter the shelter and record the temperature.

2. Leaving the shelter empty, close the door using the cardboard or equivalent. Be sure the door is closed tightly. After six minutes, enter and quickly record the air temperature.

3. Allow one person to enter, close the door and have the person record the temperature after five minutes. A flashlight will probably be required to read the thermometer.

4. Repeat 3 above with two people inside the quin-zhee.

5. Each member of the group must spend a couple of minutes in the quin-zhee in order to record what it feels like to be "subnivean". Comment on apparent temperature, light intensity and sound transmission while the door is closed. Have other group members outside the quin-zhee shout, etc. to check for sound transmission. Put comments on your data sheet.

Unless you intend to use the quin-zhee for other experiments, smash it down to prevent potential injury to inquisitive children.

Results and Discussion

Your teacher will provide you with special forms for entering and interpreting your field data. When completed, attach Data Page No. 3 to the Results/Discussion pages, add an appropriate title page and submit the report to your instructor.

Glossary

ADAPTATION

Any characteristic of an organism that contributes to its survival.

AMBIENT AIR TEMPERATURE

The temperature of the surrounding air at a specific time.

ANATOMY

The study of the structure of organisms.

BIOCLIMATE

Climate conditions such as temperature, moisture, air movement, light, etc. which immediately affect organisms.

BIOME

A region of the earth in which organisms share a common environment, usually defined by a major climate regime.

BOREAL

Northern.

BOREAL FOREST

A broad northern belt of vegetation dominated by conifers, particularly species of spruce. Also called taiga.

CHIONEUPHORES

Species of animals that can withstand winters with considerable snow, for example, moose.

CHIONIOPHILES

Species of animals whose ranges lie completely or almost completely in regions of hard and continuous winter with much snow, for example, varying (snowshoe) hare.

CHIONOPHOBES

Species of animals which do not inhabit snowy regions; snow avoiders, for example robin.

ENVIRONMENT

The total surroundings, living and non-living, of an organism.

FLOATER

Capable of walking on the snow surface, for example, snowshoe (varying) hare; grouse.

HABITAT

The place where a population of organisms lives; where one goes to find an organism.

HIBERNATION

A condition in which an organism spends the winter in a dormant state.

HIEMAL

Involving snow.

HIEMAL THRESHOLD

The point at which a sufficient thickness of snow is present to insulate the soil against changes in air termperature.

INTERFACE

A surface which is the boundary or contact point between two adjacent materials, for example, air-snow interface.

METABOLISM

The sum total of the chemical activities occurring in an organism.

MICROCLIMATE

The climatic conditions directly surrounding the living organism wherever it may be.

PUPA

A stage, usually dormant, in the life cycle of many insects between the larva and adult, for example, cocoon.

QUIN-ZHEE

A snow shelter, developed by northern Indian groups, formed by hollowing out a cavity in large pile of snow.

SUBLIMATION

A change in the state (phase) of a substance in which a solid changes directly to a gas or vice versa.

SUBNIVEAN

Beneath the snow surface.

SUCCESSION

A progressive change in the nature of the plant population of an area.

SUPRANIVEAN

On or above the snow surface.

TAIGA

A broad northern belt of vegetation dominated by conifers, particularly species of spruce. Also called boreal forest.

THERMAL OVERTURN

The time of the year at which the air temperature falls below (autumn) or rises above (spring) the soil temperature.

WADER

An animal that must walk through snow, for example, moose.

APPENDIX B

TEACHERS' COPY OF THE BASIC UNIT CONCEPTS AND RECOMMENDED MARKING SYSTEM

Teachers' Copy of the Basic Unit Concepts and Recommended Marking System

The winter ecology projects have been designed to make the student more aware of the importance of temperature and snow in the environment. Canada is a northern country and winter or near winter conditions are with us much of the year. Unfortunately, little if anything is said about winter and its effects on organisms in our science courses or authorized texts hence the development of this field ecology unit. The unit attempts to develop the concepts which are listed below:

1. Snow is crystalline water vapour and can exist in may structural forms.

2. The Inuit language can best describe snow conditions.

3. Since snow falls, it forms layers (strata) which can be recognized and roughly aged by position and crystal structure if other forces (eg. wind) have not seriously modified it.

4. Snow is an insulator and may approach the effectiveness of down.

5. Because the ground is continuously giving off small amounts of heat it is usually warmer under the snow than in the air above.

6. The ability of snow to insulate increases with depth, therefore a temperature gradient occurs in the snow cover.

7. The temperature at the snow-ground interface tends to remain constant at about -5°C throughout most of the winter.

8. The denser the snow the less effective it is as an insulator.

9. Snow in protected areas such as woods tends to be less dense and deeper than in unprotected areas.

10. The crystal structure of snow on the ground changes with time due to rising heat from the ground. Sublimation occurs, the crystals change with age and the snow becomes more dense.

11. Because of soil heat, a pukak layer gradually develops at the ground level over the winter.

12. Snow prevents light and sound from reaching subnivean organisms.

13. The properties of snow have a great impact on the

survival of organisms in Canada and other northern countries.

14. Man can take advantage of the properties of snow to construct snow shelters; in this way living in a subnivean environment becomes possible.

EVALUATION - FIELD ACTIVITY 1

PARTICIPATION IN GROUP WORK		4 Marks
PREDICTIONS (ENTERED)		2
DATA FROM SNOW STATION (RECORDED)		2
CLASS DATA - (AVERAGED)		2
TEMPERATURE GRADIENT GRAPH 1		3
TEMPERATURE GRADIENT GRAPH 2		2
DISCUSSION QUESTIONS	1	2
	2	2
	3	2
	4	2
	5	2
	TOTAL	25

EVALUATION - FIELD ACTIVITY 2

PARTICIPATION IN GROUP ACTIVITIES	4 Marks
TABLE 1 SNOW STRATA/AGE	2
TABLE 2 WEIGHT OF SNOW (STATION A)	1
TABLE 3 SNOW DENSITY (STATION A)	2
DENSITY CALCULATION	2
TABLE 4 TEMPERATURES (STATION A & B)	2
TABLE 5 DENSITY (STATION B)	2
DISCUSSION QUESTIONS 1	2
2	2
3 (a)	2
3 (b)	2
3 (c)	2
TOTAL	25

EVALUATION - FIELD ACTIVITY 3

PARTICIPATION IN GROUP WORK	4 Marks
PREDICTIONS (ENTERED)	1
QUIN-ZHEE DATA, TABLE 2, ENTERED	2
CLASS AVERAGES ENTERED. TABLE 3	2
DISCUSSION QUESTIONS 1	2
2	2
3	2
4	2
5	2
6	2
7	2
8	1
9	1
TOTAL	25

EVALUATION - FILL IN BLANKS ASSIGNMENT

50 BLANKS TO COMPLETE AT 1/2 MARK EACH.

TOTAL = 25 Marks

OVERALL EVALUATION

FIELD ACTIVITY 1	-	25 Marks
FIELD ACTIVITY 2	-	25
ASSIGNMENT	-	25
FIELD ACTIVITY 3	-	25
TOTAL MARKS	-	100

APPENDIX C

A SAMPLE PAGE FROM THE PACKAGE OF DATA COLLECTION FORMS PROVIDED TO THE STUDENTS

DATA SHEET NO. 1

NAME____________________GROUP NO.__________STATION NO._____

GROUP MEMBERS____

DATE_________________________ TIME OF DAY _______A.M./P.M.

WEATHER CONDITIONS____

____

SNOW DEPTH _______________ cm.

Predictions of Temperature in Snow

Temperature recording point	Predicted temperature
Air-snow interface	
Mid point in snow	
Snow-ground interface	

Snow Station Temperature Measurements

Recording point	Distance below snow surface (cm)	Temperature recorded (°C)
T_1	0	
T_2	5 cm	
T_3		
T_4		

APPENDIX D

A SAMPLE FROM THE PACKAGE OF RESULTS/DISCUSSION FORMS PROVIDED TO THE STUDENTS

RESULTS/DISCUSSION FORM NO. 3

NAME____DATE____________

RESULTS

Table 1. Predictions of Quin-zhee Temperatures Given an Air Temperature of -25°C

Condition	Predicted temperature (°C)
Shelter empty - door open	
Shelter empty - door closed	
1 person inside - door closed	
2 persons inside - door closed	

Ambient air temperature = _______________°C.

Table 2. Temperature Recorded Within a Quin-zhee

Condition	Temperature
Shelter empty - door open	
Shelter empty - door closed	
1 person inside - door closed	
2 persons inside - door closed	

Table 3. Average Temperatures Inside a Quin-zhee Calculated from Combined Class Data

Condition	Average temperature (°C)
Shelter empty - door open	
Shelter empty - door closed	
1 person inside - door closed	
2 persons inside - door closed	

Discussion

1. Is snow acting as insultation from the cold? Explain.

2. Is there a difference in temperature inside and outside the quin-zhee with the door open? Why?

3. Does the presence of a person(s) change the inside temperature of a quin-zhee? Comment.

4. Would a quin-zhee be a good shelter throughout the winter? Comment.

5. Other than melting the roof, what would probably happen if a heating device (with a flame) was used inside the shelter with the door closed?

6. How would you describe the environment of a subnivean mammal based on your experience inside the quin-zhee?

7. Comment briefly on your predictions compared to the actual temperatures measured inside the quin-zhee.

8. What is the point of calculating class averages of the quin-zhee temperatures?

9. Do you see any practical use for a quin-zhee?

APPENDIX E

EXCERPTS FROM ONE INTERVIEW TRANSCRIPT OF CLASS THREE

Excerpt from One Interview Transcript of Class Three

An interview was held on March 25, 1982, involving a group of four students, Q, R, S and T, from Class 3. The 80 minute interview session resulted in a lengthy transcript. Therefore, an excerpt from this interview is presented below. It will indicate to the reader the manner in which the interview was conducted and the interactions among the members of the interview group.

A series of dots (...) within an utterance indicates a brief pause.

Interviewer: Okay. Could you describe some of the different types of labs you have done over the time you have taken biology?

T: Lots of dissections in Grade 10. Everything. Worms. The starfish. Everything.

S: Uh huh.

T: That's about it. Dissection mostly.

R: We did a lot of dissections too, in Biology 10. Do you want chemistry as well?

Interviewer: Uh huh.

R: And in chemistry we did, like, mixing stuff and chemical reactions in Grade 10.

Q: We just did dissections and chemical reactions a little but ... and friction and stuff like that in physics.

S: Yeah. Just dissections and chemical reactions in both chemistry and biology.

Interviewer: Did any of you do any work with microscopes or anything like this?

T: Oh yeah.

S: Uh huh.

Q: Not much

S: Yeah, we did ... in Grade 10 ... looking at the cell and cell structures and stuff like that.

Interviewer: About how much time... maybe we can localize it to the Biology 10 program... how much time did you spend in the lab over the entire course that you were doing? (pause)

Q: Three days

S: No. More than that.

T: We had around twelve.

S: Cause we were dissecting a whole bunch of things. Like it was every third or fourth period we would dissect something.

R: We did that too. Like when we did dissections, when we started the unit, we did every second day. And that would take a whole period to do the one thing.

S: Uh huh.

T: That's what we did too. We did dissections almost every third day.

Interviewer: What is your opinion of lab work?

T: I like it. It's fun. You get to...you don't get somebody telling you how it is. You get to see for yourself.

Interviewer: Do you think there is any value in doing it?

T: Oh yeah. Lots.

Interviewer: When you say fun, what do you mean by fun?

S: Oh.

T: Well, it's not just going in there and listening to somebody telling you how it is, and you take notes down and accept it. You find out for yourself what it is, like you know, you can see it. You don't have to ... like it's something different other than notes, and listening. You can participate more.

R: Yeah. I think it's ... lab work is very important. You get to ... it's the same as she said. You get to see what is actually happening rather than being told or through textbooks.

Q: It also breaks down from the boredom too. Because you spend hours and hours and days doing the same thing over again, it kind of makes a nice break for it.

S: Yeah. I think it's worthwhile. You learn a lot more that way instead of just taking down notes all the time, and it is fun. It's a change.

Interviewer: Okay. I'll just toss this out to everybody in general. What do you consider a good lab?

(Long pause)

Assume we can classify labs as ones you would consider were good compared to ones you maybe thought were probably just as well you had not done or, if you like, a bad lab. How would you describe a good one?

T: Something that challenges you, like you don't...nothing really, really simple like ...

Q: Like grade six text books?

S: Yeah.

T: Yeah, it has to be something that you can't... you have to really be challenged in. Really dig down deep to find the information ... it's all on the surface and you kind of look at it, there it is, and you're finished.

S: Yeah, you have to more or less know your stuff. Know what you are doing...

T: Yeah

S: ... in order to do the lab. Like you don't just go there and, you know, your done in two seconds cause you know so well what you are doing.

Interviewer: One of the things that usually happens in labs... and I don't know if it has happened in ones you've had... that usually a report is expected at the end of it... or at least some documentation on what you have done. Do you think this is really necessary to go along with the lab or would you get just as much out of it by doing the lab work without having to report back on it?

Q: I think the report sort of shows what you have learned about it, so it is kind of important.

R: It depends on the lab really, too. Some of them you don't need the report cause it's just learned. Others, like when we did the snow station ... then you had to record your data cause that told you, like, the temperatures of the inside and the outside of the snow. That's what you learned.

(pause)

S: Well, I don't know. I think it is and it isn't necessary. Some of the labs you cannot do anything and just copy someone's answers and you don't know what you are doing. Then the work would come in handy afterwards, so that you could prove you knew what you were doing. But another thing. I can't think of an example. But, you know, if it's all laid out for you right then, and you have to know it before you begin, you shouldn't have to answer the questions about it.

Interviewer: Let's assume you have a report that you turn in. How do you think your lab should be graded? Assume you have a one to ten scale of marks. How would you like to see them broken down?

Q: Marks more on content.

Interviewer: Could you be more explicit?

Q: I don't know. Like what you said; how you said it.

R: Well, you would have to mark it more on... Well you have different opinions. It would be hard to mark those cause your data is what you get and it can't necessarily be wrong or right. You couldn't mark it by that. You would have to mark it as it stands. Content, as he said.

T: You have to mark how, like, your effort into it. Like, say there is a lab and somebody goofs off. You got to mark on the attitude and effort put into it. How well you recorded your data. Like, if you are going to have a report to put, in put all your information in it. Don't leave half of it out. Make it really clear.

S: I don't know. It should be mostly on content. I think cause there isn't a right or wrong answer to a lab. Like, you know, out at the snow station. Some people got really different temperatures than other people did, and that didn't mean that one person was right and the other person wrong. It's just... I don't know... the results you get are what you get.

Interviewer: Do you think lab work is necessary at all in any of your science courses, or could you have got just as much out of, say any topic you were covering that had a lot of labs with it, without ever going into the lab in the first place?

S: I think lab work is essential to all sciences. Well, I haven't taken physics. But I know some, some of the things you do, ... like cell structure and that. You can understand it without the labs, but it makes it clearer to you, I guess, with the labs. Like, you can see everything in the organization of the cell and stuff like that in biology. In chemistry well, you can see a reaction and not take someone's word for it again. You have to find out for yourself.

Interviewer: (To the other students) Could you get away without lab work?

R: I think it's very important. Lab work, it shows you everything. When we did those snow stations I really personally didn't think that we could make that, that it make really a difference, the temperatures inside and outside. But once we did it, it sure showed. It was a lot warmer inside. You wouldn't realize that unless you did it.

Interviewer:	Let's say you just had a class session and said, "Here is a pile of snow. If we take a temperature here, it's cold. If you go down, it gets warmer". You would have learned the same material. So why do the lab?
Q:	It's more interesting.
R:	Yeah. You get to do it yourself. Learn how to do it yourself and not always get a demonstration. You do it yourself.
T:	If you do it yourself, you tend to believe it more or have more reassurance other than just being told. You are going to say, "Well how does he know? Like, maybe he is pulling our leg". But if you do it yourself, you see for yourself, and you know.
Interviewer:	Okay. Let's get down to some of the snow activities you did. Could you describe a few of the activities you performed during the snow ecology unit you were doing? Any of the activities at all.
T:	The construction of the quin-zhee. We piled up the snow and hollowed it out... and took temperature readings.
S:	We did measurements of snow... and the densities of them at different layers... and we saw how the layers form and the aging of the crystals, and stuff like that in the snow.
Interviewer:	What do you mean exactly by measurements in the snow?
Q:	Taking the depth, which wasn't mentioned.
S:	Ah... well, you know... the snow piles up and, like, we were just measuring how thick the layers are and stuff like that... and the density. You know. That ... I don't know exactly how it goes but... when the snow is pushed together more, it's more

dense. Like the... they have given us an example... What kind of snow ball would you like to get hit with, you know. A more dense one or a less dense one, you know. It's kind of obvious but, you know, we found for ourselves that snow is denser when it is packed and the weight of the snow is heavier when it's denser... ha ha ... and stuff like that.

(pause)

Interviewer: Was there anything else you did... involving temperatures for example.

Q: I think we covered it all.

R: I took the temperature in the quin-zhee, inside and outside after we had finished digging it. We took the temperature of the different layers of snow.

Interviewer: Let's talk about the materials you were given to work with. If you recall, you were given two booklets, one in which you completed some exercises then you were presented with a second one. What was your opinion of the readability of these materials? How did you find the level of English, the descriptions, problems reading it. Your general opinion of the readability of the whole thing.

T: It wasn't that hard to read. If you just concentrated on what you were reading you could understand it all. The descriptions, like for... ah... different Indian terms for snow... they were all spelled out very clear.

R: It was easy to read. I had no problems reading it. The descriptions were fine.

S: It was easy to read but when we got to answer questions, I'd have to re-read it over again, as I went through the questions. I had to think about what the answers would be because sometimes they were... like just given to you... you had to think about them and know and relate what the book said... and what your work said to the questions, and come up with the answers.

Interviewer: There were no particular difficulties you ran into in interpreting what was said, then.

All: No.

Interviewer: What about the manner in which it was written? Was it interesting enough as you got into reading it or did you feel you could put it down just as quickly. Its interest level.

T: I think it was really good. Like, it gave you a little bit of information to arouse your curiosity and wants you to find out more. And then it would tell you, "Here is a lab you can do to find out more". So I found it, like, interesting. It wasn't something that I started to read and said, "Oh, boring" ... threw it away. It kept my interest up.

R: I found it very interesting, too. They went into a little kind of background, sort of, like the Indian terms, and that's something that kept your interest up. As she said, it all related to your lab. You were learning. It wasn't just for interest.

Q: I didn't find it too interesting. Laughter.
I just don't like to read too much so I don't think my opinion matters for much. I can put down any book that's fascinating to people.

S: I thought it was pretty interesting. It gave you background to what you were studying at the time. It was, overall, pretty clear to you, learned ... you got something out of it anyway.

Interviewer: What about the instructions both for performing the labs and other associated items? How did you find those ... looking at it from the point of view of how easy it was to follow the instructions or were they vague ... looking at the two extremes? What did you think of the general instructions?

S: They were pretty clear. Some people had some problems... interpreting them... no...

I don't know. It was already told to us how to go about it and what to do. So, you know. All you had to do was read through the book. It was pretty clear I guess but...

T: Any place that it wasn't clear there were diagrams.

S: Yeah.

T: Like you... if they described something and you weren't sure there was always "Refer to diagram 20", or whatever. And it would show you exactly how to do it, and there was no problem.

Interviewer: What about making the equipment? There were a couple of things you had to do. Any problems in actually making the snow samplers and the balances?

Q: Ha ha ... If you read the directions right you wouldn't have too many problems. (General laughter.)

T: It was all relatively simple and materials from everyday use. Like, so it wasn't something you would have to fly to the Yukon to get and bring back.

Interviewer: What about using the equipment once you had made it? When you went out in the field did you have any difficulties?

Q: Ha ha ha.

Interviewer: You seem to have run into a few of something. Could you describe it?

Q: I pushed the sampler in the snow and it broke (laughter). Poor construction.

Interviewer: Any suggestions for changes in equipment manufacture from your experience in using it?

(All indicated none.)

Interviewer: What about the time you had available to do the entire unit? Did you feel there was enough class time assigned to complete everything? Could you have done it in a lot less time or more time?

Q: Oh, yeah. It was the right amount of time.

S: Yeah. It was just right.

R: It seemed that when you finished, everyone else in the class was just approximate. Well, a few of the days we did have a little extra time and we would use the time to do the questions, so it worked out pretty good.

Interviewer: The data sheets you were given when you actually went out in the fields. Did you find them useful or would you have preferred to take data down in your own way?

T: No, they were useful. Like, if you would have taken it down in your own way you probably would have done it in the easiest way and maybe confused the data. Like, you probably would have had six different temperatures down but once you got back in you may not have remembered which one was for where, and this way it was all spelled out and all you had to do was just put it in the appropriate place and when you got back, interpret it. It made things real easy.

R: The sheets were fine. They had everything written down so that all you did was have to write in a number. It was a lot easier. I mean, it was so cold. You didn't have to write out a big story.

Interviewer: I get a comment from one or two individuals that in the first exercise, where you take the snow termperatures, when they got out to do them they couldn't remember exactly how they should perform the actual temperature taking. Did you find any problems with this when you went outside to do your actual experiments? Or did you have to refer back to the booklet each time you wanted to confirm anything?

Q: I think if you read it before you went into the lab you wouldn't have to do that.

S: Yeah. It was pretty straight forward in the book. I am sure if you read it over a couple of times, you know, you'd know what to do.

R: There was hard... you really didn't do that much.

T: Uh huh.

R: Like you just took your samples. That's not too hard to remember.

Interviewer: The results/discussion sheets you were also presented with to complete. Did you have any particular problems handling the instructions with them, and... let's look at it from the two things you had to do. You had to fill in data and then you had to answer the questions which were supposedly based on the data you collected. I'd like to refer to one in particular, the first sheet where you had to do some graphing of results. Did you have any problems in interpreting how to set the graphs up...

S: No, it was pretty easy.

Interviewer: ...or difficulty in plotting the points?

T: No. When the book gave you, like, gave you another diagram on how to do it. So if you just read it over and looked at that, there was no problem in setting up your own graph.

Interviewer: What about the questions? What was your opinion of them?

S: You had to think about them.

Q: They weren't too hard.

T: They were good questions.

S: Yeah. They were good questions. I learned a lot from them.

Q: I learned a few relationships.

S: Yeah. Like, some of the answers were obvious but others of them you had to think about. Kowing how to put yourself there and see what you do... kind of thing... what would happen. Like, there was one about... if you had a heating source inside a quin-zhee, what would happen besides it melting? You know, you couldn't just say, well the roof was going to melt, you know, cause that was already given to you. But, you, you really had to think about some of the questions like that.

Interviewer: Okay. When you did your work on snow temperatures... before you went out you were asked to make some predictions about what you thought you were going to get, and then you actually did take some temperatures, so you had a comparison of what you got with what you thought. Ah. Did any of you find anything different between your predictions and what you actually got?

Q: I did. I thought it would get colder as soon as you went deeper in the snow, when in fact it got warmer.

S: I wasn't too sure. I just guessed pretty well the whole way through because I... no, I didn't think it would get warmer or colder. I thought it would probably stay the same or something like that... and I was kind of shocked to see that it did get warmer like that in snow.

T: I think most people realized that it was going to change either... um... like, increase in temperature and decrease but they weren't sure which one. Probably a lot of prople put for... ah... like I know I did, like when we were measuring the snow I thought it was going to get colder too. But indeed it did get warmer. But I knew there was going to be a change somehow.

R: I had it right that it was going to get warmer but I was not even close on the temperatures, you know.

Interviewer: In what way were you not close?

R: I thought it would be lot colder than it actually was. It was still decreasing as you went deeper but.

Interviewer: What kind of impact do you think it made on you at the time?

Pause.

Or was it just a bunch of data and that's it?

R: I think it... uh... it showed to you... no, it wasn't just data. It showed to you how actually even animals could survive.. It showed it was warmer and how they could bury in the snow stay relatively warm under the conditions.

APPENDIX F

RESEARCHER'S INTERPRETATIONS OF CLASS THREE INTERVIEW MEANINGS

Interpretations of Class Three Interview Meanings

The following interpretations of student meanings parallel the interview transcript presented in Appendix D. They appear below as a series of brief paragraphs. There is a separate presentation for each of students Q, R, S and T. These interpretations, inserted at appropriate locations in a summarized transcript of the interviewees' utterances, were presented to each individual for validation following the actual interview.

Student Q

A lab is a valuable activity because you examine things on a first hand basis. The lab is also a break from regular classroom routine.

The student prefers labs which demand effort and thinking.

A lab report is important for evaluation purposes because it is a measure of what is learned. Therefore stress should be placed on the content of the report.

The lab is a more interesting way of learning material.

A dislike of reading is reflelcted in the lack of desire to read thoroughly any lab instructions even though this might affect the lab performance itself. Labs with minimum reading would be preferred.

Lack of reading resulted in poor equipment manufacture.

Reading instructions before proceding with an activity is highly desirable.

Lab reports should try to stress relationships among the data. Predicting results prior to the activity produces a more effective data collecting experience.

The student had no comments on whether the experiments had any value. Therefore, the labs probably had little value to the student other than the break in classroom routine.

Student R

Lab activities are important because they produce results which can be seen rather than second hand text information.

A simple demonstration should have no lab report associated with it since nothing new is learned. Labs involving data collection need some type of report so that the data is analyzed, helping you learn more.

Answers to guide questions and conclusions drawn from data collected should be evaluated in a report. The student's effort in doing a lab is not considered important.

Material learned in the classroom does not have the impact on the student that an appropriate lab would have. Personal involvment is critical to effective learning.

The student's attitude to a lab determines whether it is enjoyed or not.

Labs which provide information seen as potentially useful.

A good lab requires clear and interesting background information which relates directly to the investigation.

Sufficient time to complete a lab exercise is a requirement of a good lab experience.

In labs, where physical conditions are a problem prepared data recording sheets are valued. These sheets allow concentration on the experiment, not the physical conditions.

Predicting the possible results of an investigation makes the actual results more significant to the observer.

The value of the lab was not just in the data collected but that the information could be applied to understanding real, natural situations.

Student S

Labs in the sciences are of value because more can be learned by participation and the lab breaks classroom routines.

A valuable lab experience is one which requires a good background in the subject area. A challenge must be provided and the investigation should be of a reasonably long duration for a thorough study to be made.

Lab reports should be submitted only if the investigation produces something which has further application, not for a "confirmation" type of lab. If the concept to be studied by the lab is not clear the lab report becomes a useless experience. Clarity of purpose in a lab is of high value for the student.

Priority in evaluation of labs should be given to the discussion and interpretation of the data collected, not to the data alone. Interpretation of data is of higher value to the student.

First hand experience is of much greater value to the student than learning by book; the student is thus prepared to accept book data more confidently.

The materials provided enough background information to make reading them of value to the student. Because the background material related to the results they were of more value to the student.

Diagrams are valuable to aid instructions in a lab. Discussion of an activity in class prior to the lab is of value to the student.

Having sufficient time to complete a lab properly is of value to the student.

Guide questions which make the student think are valuable because they result in greater learning.

Reading instructions carefully prior to a lab is of value when actually performing the activities.

Prediction of results followed by data collections and comparisons is of considerable value to the student.

Student T

Lab work is a valuable activity for the student. It is enjoyable because it breaks with normal class activities, involves group work and first hand experiences occur.

A lab which challenges the student is of greater value than one with few demands.

Effort, attitude and accuracy of data recorded are high priority aspects of lab report evaluation.

The "seeing is believing" aspect of lab work makes it a superior learning experience to regular classwork.

Clarity of instructions and materials are an important aspect of lab work.

A lab activity which initiates interest then required the student to find out more is of higher value than one which simply confirms known ideas.

Diagrams are valuable in lab instructions, where applicable.

The student was satisfied with making and using lab equipment.

Having sufficient time to complete the lab is of value to the student.

Pre-prepared data collecting forms are preferred to student designed ones, because they focus in on the situation and lead to more satisfactory interpretations.

Clear descriptions of procedures are easily remembered and thus make the lab more effective.

Clearly presented techniques in reporting the data and good questions make the lab report more effective.

Predicting results, then comparing them to actual data, is an effective way to learn lab information.